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J. Rybinski, et al

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by

Jerzy Rybinski
Aleksandra Zelechowska
Zbigniew Makowski
Romuald Ceglarski
Elzbieta Heybowicz
Institute of Meteorology and Water Management
Maritime Branch
Department of Water Protection
80-252 Gdansk

JB-5-534-6

Project Officer

Lynn R. Shuyler
Animal Production Section
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

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16. ABSTRACT

The efficiency of Barriered Landscape Water Renovation (BLWRS), 1500 m^2 in size, to renovate flushed slurry from the industrial pig farm was studied during two years of exploitation. Applying annual loading rates of 1000 mm of slurry pretreated mechanically and, separately, coagualted with teh use of aluminium sulphate, resulted in the following daily loading rates of: COD 0.0178-0.0604; TN 0.0037-0.0079; TKN 0.0034-0.0070; and TP 0.0005-0.0034 kg/m^2, and the following removed percentages: COD 90.4-98.8%; TN 64.2-89.4%; TKN 74.9-96.4%; and TP 96.6-99.8%.

A water budget for BLWRS was prepared, transformations of volatile solids, COD, TN, TKN, organic nitrogen, oxidized nitrogen forms and TP occuring in the bed at the different BLWRS depths were described. An oxygen balance for the BLWRS was developed, the effect of metals removal was described, and the influence of temperature on the occuring processes as well as its influence on the possibility of full-time operation was defined. The obtained results were compared with similar, but carried out in the smaller scale investigations, which were published in 1974 by Erickson. This work was done within the frames of Maria Curie-Sklodowska Fund in cooperation with the American Environmental Protection Agency. The experimental part of the work was completed on March 31, 1981.

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma, is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in ground water and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for controlling pollution from petroleum refining and petrochemical industries; and for managing pollution resulting from combinations of industrial/industrial and industrial/municipal wastewaters.

This project was initiated to investigate the use of the Barriered Landscape Water Renovation System (BLWRS) for the treatment of slurry wastes from large scale hog production operations both in the United States and Poland. The project was designed to study the operation of the BLWRS in conjunction with the conventional treatment plant already in use at the industrial hog farm near Gdansk, Poland. The study investigated the overall efficiency of the BLWRS using several pretreatment options from the conventional plant, different energy sources and different phosphorus removal media on the BLWRS surface. The results indicated that the BLWRS could be used efficiently with various components of the existing conventional treatment system acting as a pretreatment system, and that the BLWRS could be operated 8 out of 12 months in the cold climate of Northern Poland. The results have provided most of the design functions necessary to enlarge the BLWRS for full scale operations. The information contained in this report will be very useful to both countries in the evaluation of future conventional treatment systems for swine wastes and for the design of full scale BLWRS units for any type of agricultural wastes.

Clinton W. Hall

Clinton W. Hall, Director
Robert S. Kerr Environmental
Research Laboratory

ABSTRACT

The efficiency of Barriered Landscape Water Renovation (BLWRS) - 1500 m^2 in size, to renovate flushed slurry from the industrial pig farm was studied during two years of exploitation. Applying annual loading rates of 1000 mm of slurry pretreated mechanically and, separately, coagulated with the use of aluminium sulphate, the following results were obtained:

	Loading ($kg/m^2.d$)	Percent of Removal
COD	0.0178 - 0.0604	90.4 - 98.8
TN	0.0037 - 0.0079	64.2 - 89.4
TKN	0.0034 - 0.0070	74.9 - 96.4
TP	0.0005 - 0.0034	96.6 - 99.8

Water budget for BLWRS was prepared, transformations of volatile solids, COD, TN, TKN, organic nitrogen, oxidized nitrogen forms and TP occurring in the bed at the different BLWRS depths were described. An oxygen balance for the BLWRS was developed, the effect of metals removal was described, and the influence of temperature on the occurring processes as well as its influence on the possibility of full-time operation was defined. The obtained results were compared with similar, but carried out in the smaller scale investigations, which were published in 1974 by Erickson. This work was done within the frames of Maria Curie-Sklodowska Fund in cooperation with the American Environmental Protection Agency. The experimental part of the work was completed on March 31, 1981.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BLWRS	-- Barriered Landscape Water Renovation System
kmol	-- kilomol
mm	-- millimeter
cm	-- centimeter
m	-- meter
m^2	-- square meter
dm^3	-- cubic decimeter
m^3	-- cubic meter
mg	-- milligram
mbar	-- millibar
kg	-- kilogram
ppm	-- pars per million on a weight basis
l	-- liter
t	-- time
T	-- temperature
V	-- velocity

SYMBOLS

TN	-- total nitrogen
TKN	-- total Kjeldahl nitrogen
$N\text{-}NH_4$	-- ammonia nitrogen
N_{org}	-- organic nitrogen
$N\text{-}NO_3$	-- nitrate nitrogen
$N\text{-}NO_2$	-- nitrite nitrogen
N_{oxid}	-- oxidized forms of nitrogen $N\text{-}NO_3 + N\text{-}NO_2$
TP	-- total phosphorus
C_{org}	-- organic carbon
C_{inorg}	-- inorganic carbon

VSS	-- volatile suspended solids
VSS_O	-- volatile suspended solids contained in the raw wastes
ortho P	-- orthophosphorus
SS	-- suspended solids
SS_{om}	-- content of the suspended solids, form the raw wastes, at "m" depth
VSS_m	-- volatile suspended solids at "m" depth
VSS_{om}	-- volatile suspended solids from the raw wastes at depth "m"
VSS'	-- volatile suspended solids of BLWRS biomass
TSS	-- total suspended solids
L_r	-- removed load of impurities
L_{app}	-- applied load of impurities
H	-- hydrogen
C	-- carbon
P	-- phosphorus
Cl-	-- chlorine
O_2	-- oxygen gas
K	-- potassium
N	-- nitrogen
Na	-- sodium
Ca	-- calcium
Mg	-- magnesium
Fe	-- iron
Zn	-- zinc
Cu	-- copper
Al	-- aluminium
Cd	-- cadium
Mn	-- maganese
T_{exp}	-- student's test, experimental value
T_t	-- student's test, table value
BOD	-- biochemical oxygen demand
COD	-- chemical oxygen demand
COD_{sol}	-- COD of the soluble fraction of wastes
COD_m	-- COD of the wastes at "m" depth
TOD	-- total oxygen demand

ACKNOWLEDGEMENTS

We express our gratitude to the managers of the industrial pig farm in Czernin for making possible BLWRS construction, operation, and demonstration.

We gratefully acknowledge the support, consultations, and overcoming the difficulties (which neither we nor he could foresee) from the Project Officer, Lynn R. Shuyler.

We would like to thank the consultants Professor Raymond C. Loehr, Professor Frank J. Humenik, William C. Galegar, Dr. James P. Law and all the others from America, who thanks to their kindness and knowledge, in our close contacts with them, contributed to the realization of this work.

We also thank the large group of the employees of the Institute of Meteorology and Water Management who in some way or another contributed to this research.

SECTION 1

INTRODUCTION

The modified soil filter with impermeable barrier called a Barriered Landscape Water Renovation System (BLWRS) constitutes a solution which enables the considerable elimination of organic substances and other nutrients from the slurry. The removal degree of these impurities indicated in previous work suggests the possibility of BLWRS utilization even for the renovation of water from the wastes and recycling it for the reuse on the farm. Moreover this system seems to be useful in these cases, where because of the lack of available land for agricultural utilization of animal wastes, it is necessary to use pretreatment or even complete treatment and discharge.

The aim of this work is to demonstrate the operation of BLWRS at a technical scale and in combination with a conventional treatment system during the two-year period of investigations, using slurry from industrial pig farm using no bedding as the source of impurities. The system combination consists of removing Suspended Solids (SS) from the slurry before applying it to the BLWRS which was attained by filtering on the screens, and sedimentation as well as by coagulation. These preliminary treatment processes were foreseen to decrease the mechanical pollution of the BLWRS surface.

The first industrial pig farm in Poland was built in 1972. Since then the total number of the industrial size pig farms has increased to 145, their scale and production are presented in Table 1. The farm utilized for this project is located near Gdansk at a small village called Czernin (Figure 1).

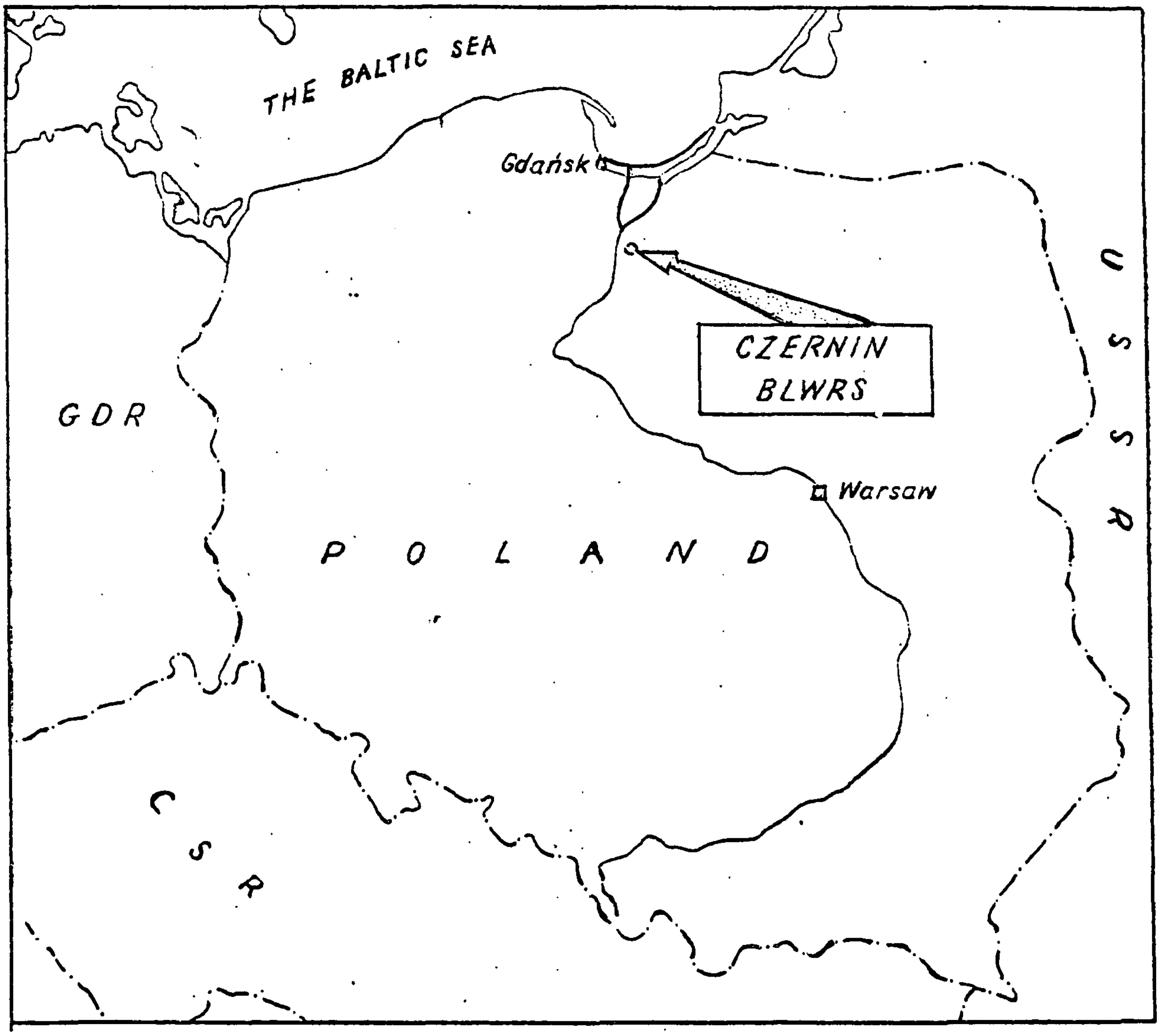

Figure 1. Location Map.

TABLE 1. INDUSTRIAL PIG FARMS IN POLAND (Krasnodebski 1978)

Production Scale Thousands of Animals	Number of Farms Units	Annual Production of Porkers of 110 kg Weight; Animals
6 - 10	47	322,000
11 - 20	73	1,083,000
21 - 30	9	252,000
31 - 45	16	616,000
Total	145	2,273,000

The management of the slurry from the industrial farms runs according to the four basic principles:

1) direct slurry transportation to the fields;
2) direct watering of the fields with the liquid phase of the slurry and periodical solids removal;
3) lagooning of the slurry before agricultural utilization; and
4) purification of the slurry in the treatment plant and discharge of the effluent to the surface waters.

The last method is applied in the case where the farm has no available land for agricultural utilization of the slurry. About 10 percent of the animal industrial farms are in this situation.

Slurry from each of the industrial farms differs mainly in quantity and concentration; however, the quality differences, caused by the kind of diet as well as by the method of feeding, also appear. Water consumption in industrial farms ranges from 5 to 40 liters (l) per day per pig, depending on the farm type as well as on the way of cleaning the building and removing the slurry. The composition of the slurry obtained from the data given by Kutera (1980) and from our investigations are presented in Table 2.

TABLE 2. CHARACTERISTICS OF THE SLURRY FROM THE INDUSTRIAL PIG FARMS

Parameter	Unit	Value
Specific Gravity	g/cm^3	0.90 - 1.015
Totals Solids	g/m^3	9,000 - 80,000
Ash	g/m^3	2,000 - 22,000
Volatile Solids	g/m^3	7,000 - 58,000
pH		7.1 - 7.4
BOD_5	gO_2/m^3	2,500 - 16,000
COD	gO_2/m^3	6,000 - 46,000
Total Nitrogen	g/m^3	600 - 4,800
Phosphorus	g/m^3	250 - 1,500
Potassium	g/m^3	300 - 4,000
Calcium	g/m^3	300 - 2,000
Magnesium	g/m^3	120 - 600
Sodium	g/m^3	150 - 600

The high concentration of the slurry and the location of the farms, generally on lands situated far from the larger water ways, require a high degree of waste purification to reach an effluent quality which will allow the discharge of purified wastes to the surface waters.

The regulations which are obligatory in Poland (Rozp. Rady Min., 1975) divide surface waters, depending upon their utilization, into three classes, i.e.:

Class I - waters reserved for the supply of drinking water;
Class II - waters designated for the animal husbandry, recreation, and watering - places; and
Class III - waters designated for industry and agriculture.

Each class has a definite permissible pollution level which can occur in the river at the average low water level (Table 3), after the purified wastes were discharged into this river. Exceeding this level is punishable by fines. Therefore, the larger the amount of slurry, the smaller the receiver and the higher class of water, the higher the degree of purification that is necessary.

TABLE 3. ADMISSIBLE CONCENTRATIONS OF THE POLLUTANTS IN THE INLAND SURFACE WATERS (ONLY PARAMETERS CHARACTERISTIC FOR THE SLURRY)

Parameter		Unit	Purity Class		
			I	II	III
Dissolved Oxygen	a[1/]	mg O_2/1	6.0	5.0	4.0
BOD_5	b[2/]	mg O_2/1	4.0	8.0	12.0
COD	b	mg O_2/1	40.0	60.0	100.0
Chlorides	b	mg Cl/1	250.0	300.0	400.0
Sulphates	b	mg SO_4/1	150.0	200.0	250.0
Ammonium Nitrogen	b	mg N/1	1.0	3.0	6.0
Nitrate Nitrogen	b	mg N/1	1.5	7.0	15.0
Organic Nitrogen	b	mg N/1	1.0	2.0	10.0
Phosphates	b	mg PO_4/1	0.2	0.5	1.0

1/ a - not less than
2/ b - not more than

The present methods of slurry purification are based on filtration, sedimentation, coagulation, biological cleaning in the tanks with activated sludge or in the lagoons (one of these purification plants is described in section 4), don't always give satisfactory results. Therefore, using the soil environment with the process modification for nitrogen and phosphorus removal, as the final stage of animal waste purification seems to be sensible. The combinations of BLWRS with other methods of preliminary purification of slurry constitutes the system studied.

SECTION 2

CONCLUSIONS

1. The 2 year period of BLWRS operation indicated that temperature decrease in December, leading to the icing of BLWRS surface makes operation of the BLWRS system practically impossible. Starting BLWRS again appeared to be possible only after a 4 month break which results in a period of system operation during the calendar year no longer than 8 months, i.e. from April to November.

2. Independently from the stops in operation caused by the low temperature, it is necessary to apply breaks in feeding, resulting from the overloading of BLWRS surface, which reduces the period of BLWRS feeding to about 200 days during the year. Annual dose of the wastes applied to the adapted BLWRS, at the used loading, slightly exceeded 1000 mm, corresponds to about 4.0 mm/day in the 8-month period of favorable temperatures and about 5.0 mm/day on the average during the 200 days of effective waste feeding of the BLWRS.

3. BLWRS water budget including applied wastes, precipitation, evaporation, and change of retention in BLWRS, closes with the losses amounting to 13 percent on the average, which is recognized as a satisfactory result.

4. The variation of the impurities in the waste composition and applied hydraulic loadings of the BLWRS were: COD 0.0178 - 0.0604; TN 0.0037 - 0.0079; TKN 0.0034 - 0.0070; and TP 0.0005 - 0.0034 $\frac{kg}{m^2 . day}$, depending on the BLWRS section and the calendar year.

The obtained effect of the elimination of impurities from slurry equals on average for the whole demonstration period:

	For the Sections Without Energy Insert	For the Sections With the Additional Energy Source
COD	97.3%	95.5%
TN	79.0%	77.4%
TKN	91.2%	84.1%
TP	99.2%	98.9%

On the basis of the above presented information as well as the other results contained in this work, it can be concluded that using the energy insert for the denitrification process in the form of the sludges separated from slurry on the screens and composted, doesn't give expected results and on the contrary constitutes the source of the additional pollution. The definite relationship between the removed and applied loading was also stated and expressed by appropriate equations.

5. The transformations of impurities in BLWRS vertical profile for different forms of Nitrogen (N), Chemical Oxygen Demand (COD), Total Phosphorus (TP) and Suspended Solids (SS), analyses based on the sets of average values from the whole exploitation period can be expressed by the equation:

$$\frac{c_m}{c_o} = b\ m^a \qquad (1)$$

6. COD of slurry on the different BLWRS depths indicates correlation with Organic Carbon (C_{org}) with the slope coefficient equal 3.0987.

7. The removal of phosphorus from the wastes can be expressed by Langmuir and Freundlich isotherms while in the second case the correlation is slightly higher. The differences in the effects of phosphorus removal

from BLWRS purifying the wastes after coagulation with aluminium sulphate and from the BLWRS with the layer of blast-furnace slag fed with slurry without coagulation, were not observed.

8. The trial of the kinetic approach to the process taking place in BLWRS on the basis of various order of kinetic reactions for the whole data set didn't result in the satisfactory correlation coefficients. These results can be arranged only by the Haseltine function, describing the relationship between the removed and applied loading, which after appropriate transformation leads to the expression:

$$\frac{Q}{F} = \frac{m}{c_o} \sqrt[1-b]{\frac{a}{\eta}} \qquad (2)$$

where:

- Q - amount of wastes applied to BLWRS, 1/day,
- F - BLWRS surface, cm^2
- m - thickness, cm
- c_o - concentration of the investigated parameter in the waste applied to BLWRS, mg/1
- c_m - concentration of the investigated parameter in the waste, after the BLWRS layer of m thickness, mg/1
- η - purification efficiency = $\frac{c_o - c_m}{c_o}$
- a,b - equation parameters

9. Oxygen balance for BLWRS indicates that oxygen demand for the processes of mineralization and oxidation, proceeding in the bed, can be covered by the exchange of soil air.

10. The comparison of the effects of slurry purification on the adapted BLWRS in the period of favorable temperatures (average value +12.7°C) with the month of the average temperature equal +3.9°C indicates the decrease of the purification effect mainly in the range of total nitrogen (TN).

11. The investigation of ions of metals in the slurry passing through BLWRS shows the fixation of considerable amounts of K, Na, Zn, Cu, Fe, Al, and Cd in bed while the degree of their removal decreases with the increase of the time of BLWRS exploitation. However, the elution of Ca and Mg ions from BLWRS bed was observed most clearly during the second year of the experimental object's exploitation. The layer of blast-furnace slag increases, additionally, the amount of leached Mg.

The influence of energy insert on the increased leaching of iron compounds and to some degree potassium (K), from BLWRS bed, was also noticeable. The low Cd concentration in the applied wastes indicates that in Polish conditions this metal is not a problem.

12. Loading BLWRS with wastes causes the increase in concentration of most of the investigated parameters, most noticeable in the upper 30 cm of the soil profile. The accumulation of nutrients is most evident in the case of C_{org}, Volatile Suspended Solids (VSS), and Total Kjeldahl Nitrogen (TKN). The accumulation of substances in BLWRS bed at the end of 1979 and 1980 doesn't show significant differences, which reflects the development of some state of equilibrium.

13. Comparing the total effects of purification, in the range of basic indicators, received in this work with the results of Erickson's (1974) investigations, in the case of comparable section without energy insert, the compatibility of the results were obtained with a slightly worse TKN elimination and lower BLWRS loadings in the second year of the study.

SECTION 3

RECOMMENDATIONS

It is recommended to continue the investigations on the system in the application also to the wastes other than animal wastes, as well as in the case of the animal farm as the final degree of water purification and renovation after the biological stabilization of wastes with the process of the partial nitrogen elimination.

The system's sensibility to the negative influence of the low temperature and the limitations in the use of BLWRS during winter months in the climate with the temperatures below $0^{o}C$ should be considered.

However, it is recommended to test this system in unfavorable temperature conditions using a feeding system different from sprinkling.

SECTION 4

EXPERIMENTAL PROCEDURES

SYSTEM DESCRIPTION

Farm Description

The experimental BLWRS was situated on the grounds of the large, industrial pig farm of the Gi-Gi type, in the Czernin State Collective Farm. The pretreated wastes from this farm constituted the wastes applied to BLWRS. During the complete production cycle, this farm was inhabited by 27,500 hogs, the characteristic of this stock is presented in Table 4. These numbers describe the stock at the end of the year, while the variations during 12 months reach $\pm 10\%$.

TABLE 4. DISTRIBUTION OF HOGS AT CZERNIN FARM, END OF YEAR

Year	Boars	Breeding Boars	Left Sows	Sows of 7 Months and Older	Young Pigs	Piglets	Sows	Other Pigs
1979	87	29	-	783	12,834	8185	2252	5125
1980	106	-	1653	1503	11,271	8957	2165	4227

This farm includes the complete production cycle and with the annual production reaching 36,000 porkers of an average weight of 110 kg per pig. A schematic diagram of this farm is presented in Figure 2. The energy consumption of this farm is 289,000 KWh annually, while the average water consumption reaches 800 m^3/day.

In the Gi-Gi type farm the animal wastes from the pen and the waste feed from troughs are removed each day with flush water to the internal

1A, 1B, 1C - Buildings for covering and gestation

4A, 4B, 4C - Buildings for delivery and feeding

5A, 5B, 5C - Piglets' buildings

8A - 8L - Buildings for fattening (buildings for porkers)

2 - Building for quarantine and breeding of the little boars

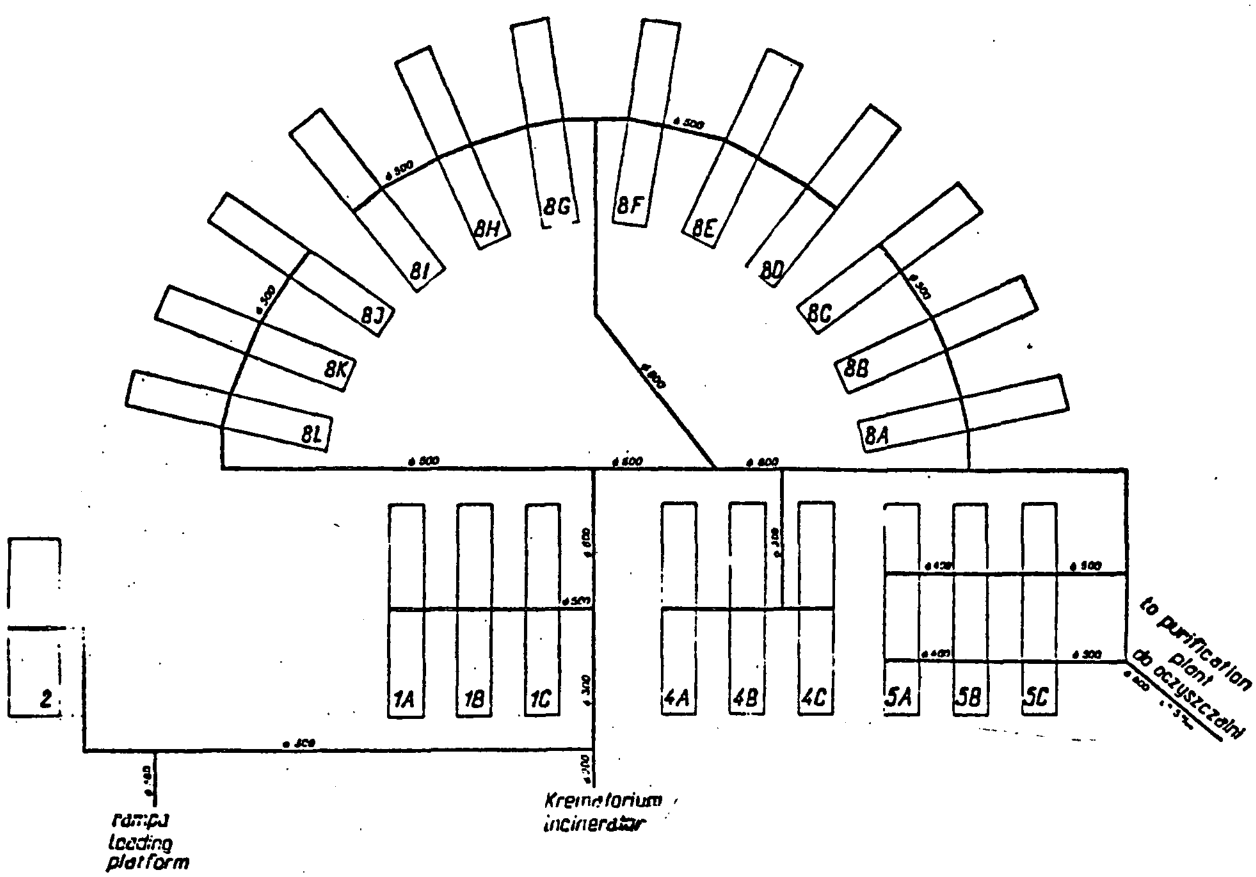

Figure 2. Schematic diagram of production buildings and slurry canals in the Gi-Gi type farm.

slurry canals. Animal wastes are transported through the system of collective slurry canals, flushed with water, to the purification plant. The farm described has a complex purification plant, which includes mechanical, chemical, and biological waste treatment. This animal waste purification plant was designed and constructed by the Hungarian firm "Tatabanyai-Szenbanyak".

Description of the Purification Plant

The diagram of the Hungarian purification plant of the Vidus type is presented in Figure 3. Slurry, averaging 800 m^3/day, flows by gravity through collector canals to the pump station. To protect the pumps against damage, gratings were installed before the pump station tank. The tank of the pump station has a capacity of 54 m^3 and is equipped with two pumps and a mechanical stirrer to prevent the settling of the impurities at the bottom. From the pump station slurry is lifted into the distribution tank from which it flows to the four dynamic screens of 0.4 - 0.6 mm sieve mesh. The excess slurry from the distribution tank is recirculated through an overflow back to the pump station. The effluent from the screens flows gravitationally to the equalizing and preliminary aeration tank where the equalization of the composition of the wastes takes place as well as preaeration with the use of two deep aerators. The surplus activated sludge is also recirculated to this tank. The chemical purification process is based on the coagulation of the preaerated mixture of the raw slurry and the surplus of the activated sludge with the aluminum sulphate using a dose of 1 kg of $Al_2 SO_{4\ 3} \cdot 18H_2O$ for 1 m^3 of waste.

The wastes from the equalizing tank is pumped through the heat exchanger, combined with the coagulant solution in the mixer and in the reactor, and then the mixture flows to the two preliminary settling tanks. The separated sludge is pumped to the sludge thickener. Sludge supernatant from the thickener flows to the pump station while the thickened sludge is carried to the sludge sand beds.

1. Raw slurry pump station
2. Tank for distribution into the dynamic screens
3. Dynamic screens
4. Preaeration tank
5. Tank for coagulant solubilization
6. Storage tank for coagulant solution
7. Pump
8. Coagulant dosing pump
9. Mixing tank for coagulant and raw wastes
10. Reactor
11. Tank for distribution into the preliminary settling tanks
12. Preliminary settling tank
13. Sludge thickener
14. Sludge pump
15. Tank for distribution into the aeration chambers
16. Aeration tank
17. Distribution tank for the activated sludge
18. Recirculation pump
19. Secondary settling tank
20. Disconnected biological filter
21. Disinfection chamber

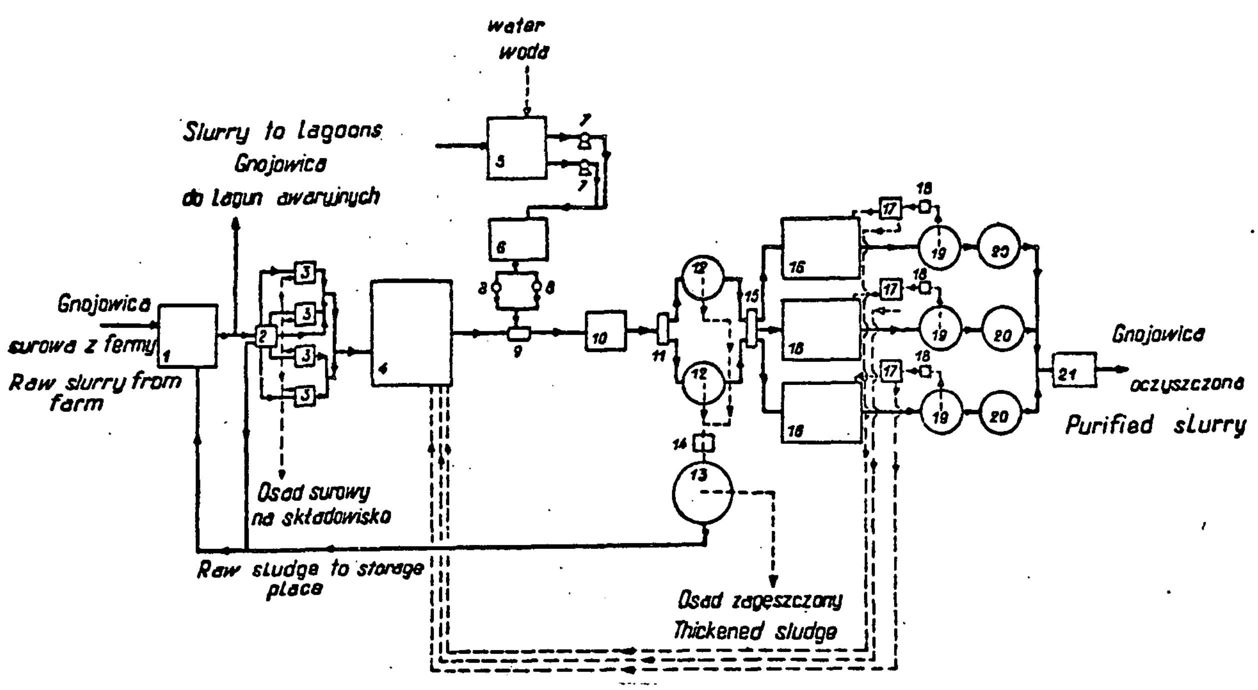

Figure 3. Schematic diagram of Vidus type purification plant.

The biological purification of the wastes is the first stage process and runs in three parallel lines. The waste purification is attained here by the activated sludge method. The clarified wastes in the preliminary settling tanks flow gravitationally through distributor to the aeration tanks, 170 m^3 of capacity each, which are equipped with aerators. The content of the aeration tanks flows to the secondary settling tanks and after clarification, it is directed to the disinfection chamber where the purified wastes can be disinfected with sodium hypochlorite if necessary. The activated sludge separated in the secondary settling tank is pumped through the distributor and some part of the recycled sludge returns to the aeration tank while the surplus sludge flows to the equalizing and preliminary aeration tank.

BLWRS Description

The experimental BLWRS is located near the treatment plant (Figure 4). The BLWRS method of waste purification was tested on a 1500 m^2 area divided into two filter beds, and fed with wastes independently (Figure 5). Both beds were formed from sand of a granulation shown in Figure 6 and of the chemical characteristics contained in Table 5. The filtration coefficient of the applied sand was in the range of 2.57 - 4.63 x 10^{-2} cm/sec. Both beds were constructed in an artificially formed earth basin, which was sealed with a waterproof barrier made of a double layer of polyethylene foil with control drainage pipes laid between foil sheets. Each of the two BLWRS was further divided into two sections (Figure 7). One section of each BLWRS was equipped with a wooden channel to which the additional energy source for denitrification was introduced (Figure 8). The other section had no energy insert. Sludge separated from the animal wastes during filtration on the dynamic screens and then stored for one year on the field was used as the additional energy source in these investigations. The elementary composition of that sludge, for the basic constituents, was as follows: C- 43.13%, H - 5.85%, and N - 1.87%.

Sand above the foil was 1.8 m thick, the BLWRS beds were divided into two horizontal zones: an aerobic zone of 1.2 m and the underlying saturated anaerobic zone of 0.6 m which was created by damming up the waste effluents with the use of a siphon device.

1. BLWRS
2. Animal farm
3. Existing chemical and biological waste purification plant
4. Boiler room
5. Sludge lagoons
6. Sewage ponds

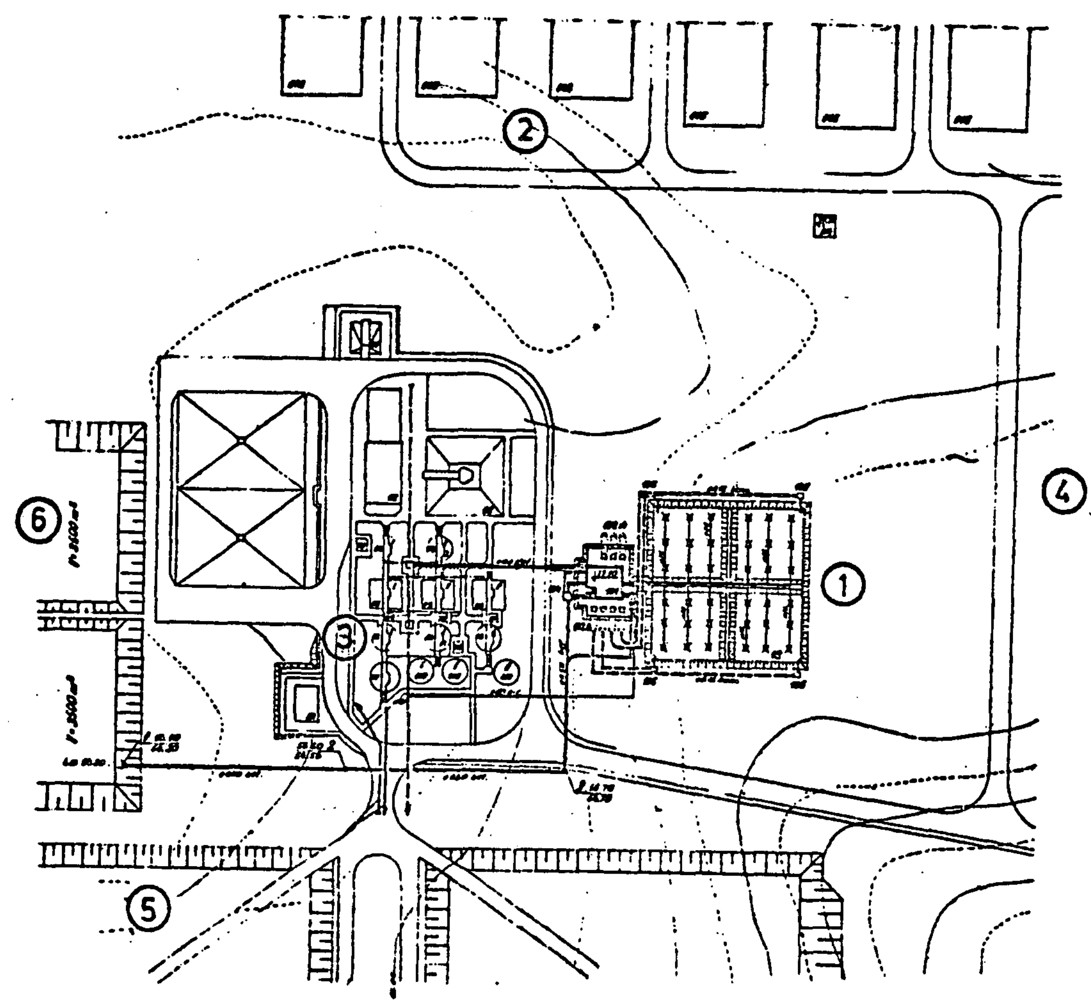

Figure 4. Location of BLWRS.

1. Waste inlet
2. Feeding tanks
3. Pump station
4. BLWRS-34 with additional energy source
5. BLWRS-12 with additional energy source
6. BLWRS-34 with no energy source
7. BLWRS-12 with no energy source
8. Additional energy source
9. Installation of sprinklers
10. Effluent drain
11. Effluent installation
12. Effluent holding tanks
13. Purified waste outlet
14. Water - supply system
15. Septic tank

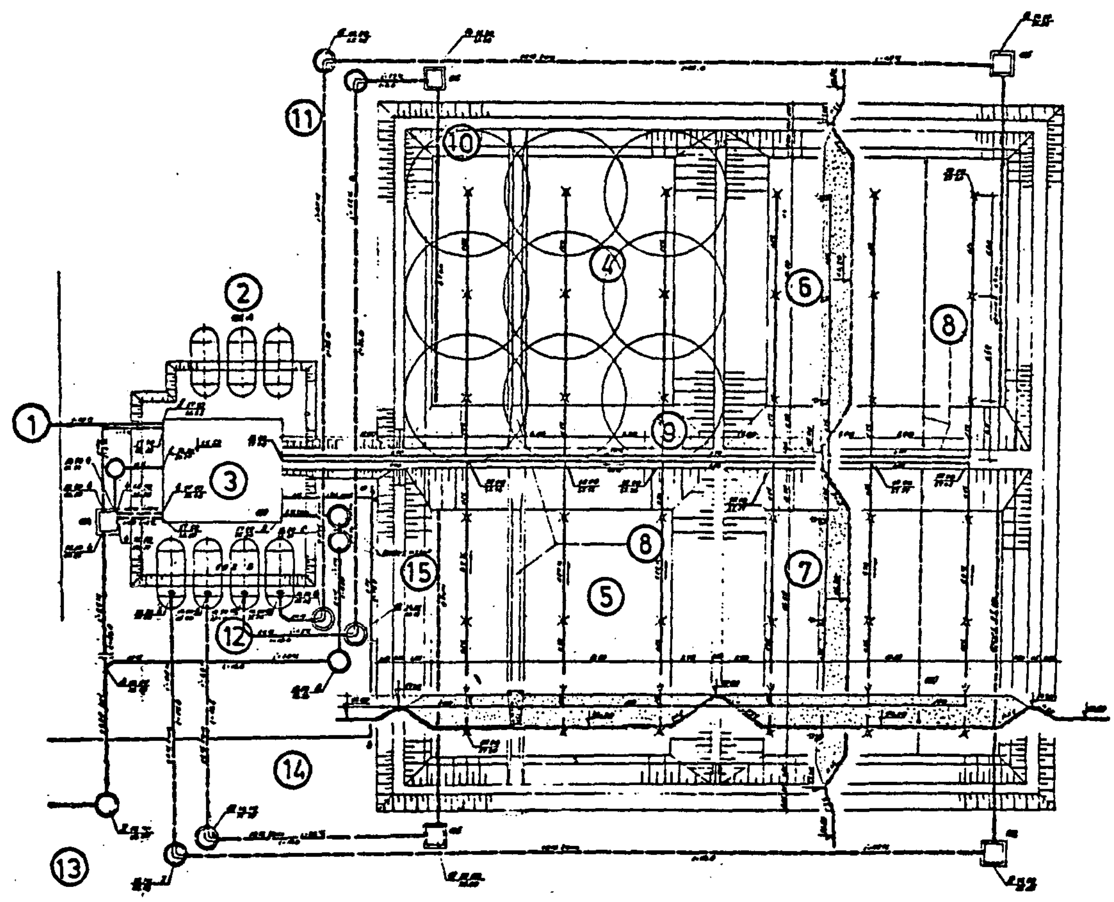

Figure 5. BLWRS and external installations.

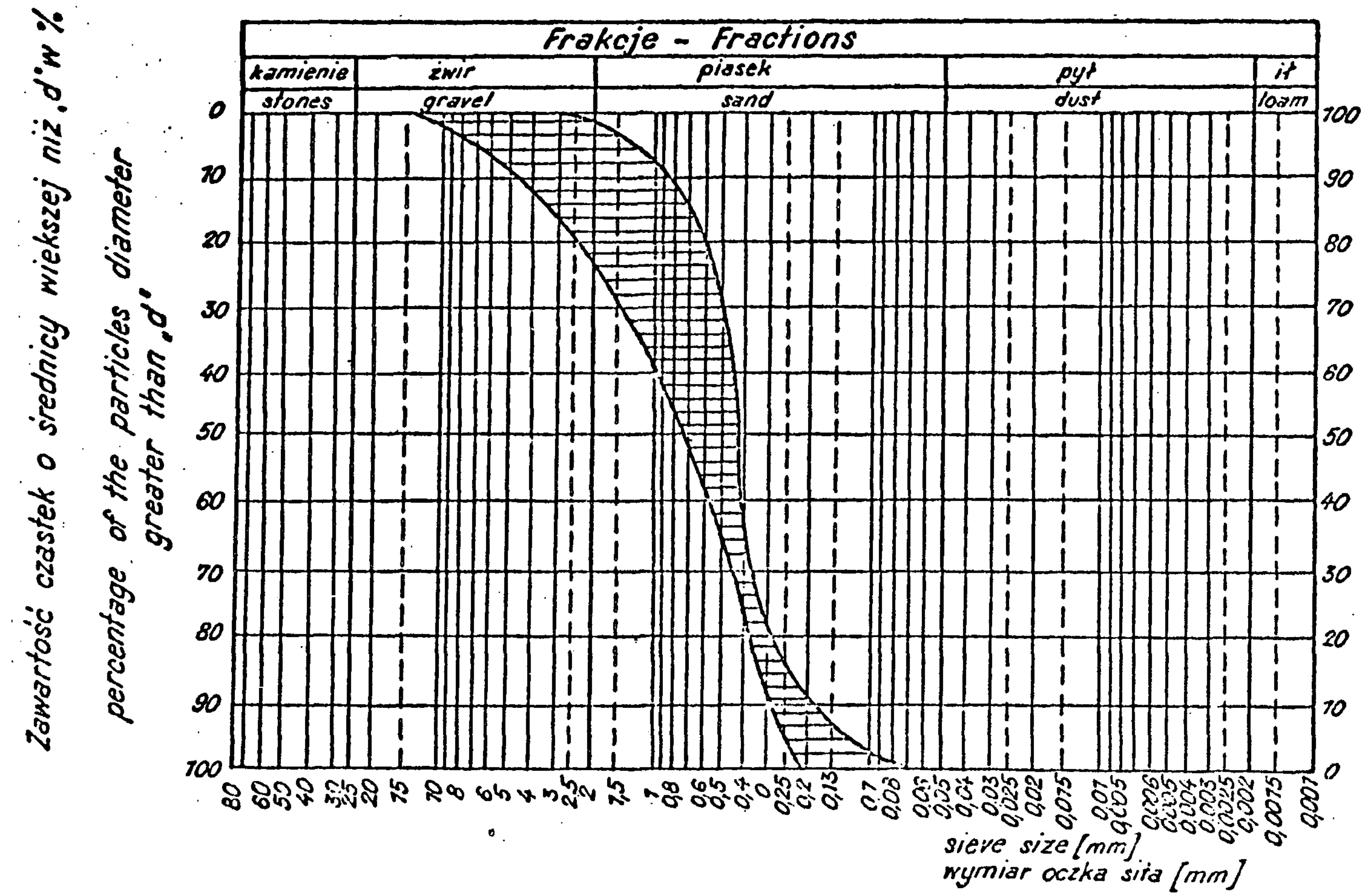

Figure 6. Range of ground granulation diagrams for eight samples from BLWRS.

TABLE 5. CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE ORIGINAL BLWRS SOIL (CONCENTRATIONS IN PPM)

Total Organic Solids	43,700.0
Organic Carbon	10,750.0
Inorganic Carbon	7,300.0
TKN	55.0
Total Phosphorus	270.0
Potassium	890.0
Sodium	18.8
Calcium	22,235.0
Magnesium	1,750.0
Copper	4.75
Zinc	15.0
Iron	2,587.5
Aluminium	975.0
Bulk Density	1.55 g/cm^3
Porosity; solid 62.5%; porespace =	37.5%

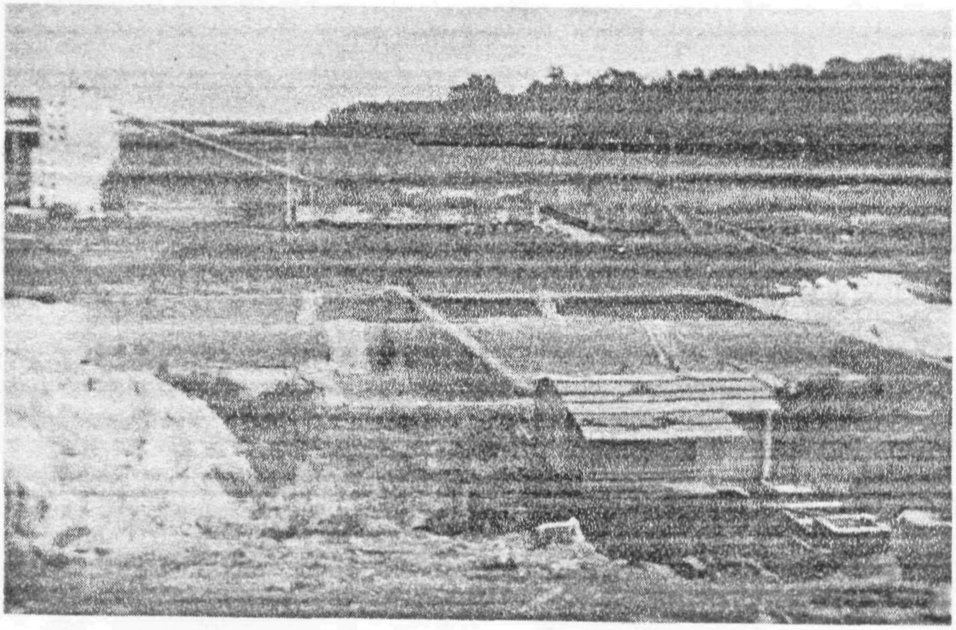

Figure 7. Artificial earth basin prepared for 4 sections of BLWRS.

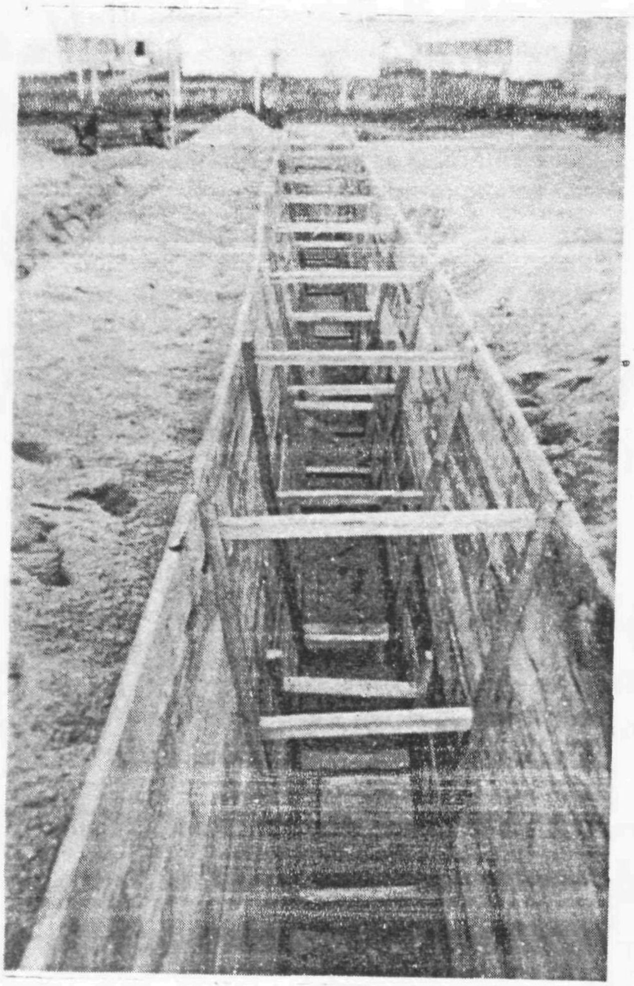

Figure 8. Installation of the additional energy source.

Both BLWRS were fed with wastes from the described purification plant, taken before and after coagulation. A continuous process of sedimentation was applied to the wastes before the coagulation. This process was carried on in an additionally installed vertical settling tank which had a detention time of 2 hours. The second type of wastes were drawn directly from the treatment plant just after coagulation with the $Al_2\ SO_4\ _3$ x 18 H_2O used at the dose of about 1.0 g/dm^3. Wastes treated in the above described ways were introduced into special tanks of 10 m^3 capacity each, from where they were periodically spread on the top of the suitable BLWRS (2-5 minutes per hour). Effluent from each of the four sections was obtained by an individual pipe system to a separate tank of 10 m^3 capacity. All tanks were equipped with devices for measuring volume, and they were emptied by the use of pumps started manually after the waste volume measurement had been done.

To make the information more precise, the system fed with the animal wastes after coagulation, consisting of Sections 1 and 2 are described as BLWRS-12 and the second system consisting of Sections 3 and 4 are called BLWRS-34.

The BLWRS were equipped with thermometers for the measurement of ground temperature at depths of 5, 10, 20, and 50 cm, and a meteorological station was located near the BLWRS site. The pluviometer, barograph, thermograph, evaporimeter, anemometer, minimum thermometer, and maximum thermometer were installed in that station. Moreover in Section 2 of BLWRS-12, two membrane probes for determination of the percentage of oxygen content in the soil air were installed at the depth of 60-80 cm.

MATERIALS AND METHODS

System of Sampling and Waste Quantity Measurement

The same quantity of samples, from the analogically situated points, was taken from each section of BLWRS, which constituted four separate systems as far as the technological parameters were concerned. The samples from the aerobic zone were taken at four places from two depths, 30 and 80 cm, to form an average sample for each layer, so the BLWRS supplied four samples from the aerobic zone. In the anaerobic zone the sampling took place also at four places from two depths, 140 and 160 cm; however, two average samples were formed for each depth and each section of the BLWRS. Therefore at each sampling time, samples from 64 points were collected and then 20 average samples were formed. At the same time, samples of the two kinds of wastes fed to BLWRS and four samples of the BLWRS effluents were taken.

A collecting plate and a container filled with gravel (8-10 mm granulation) were installed at each sampling point in the aerobic zone. The gravel filled pot served as a container for the collection of the sampled liquid. A PCV drain pipe filter was installed in the gravel, on a conduit which was led out above the BLWRS surface. Percolating wastes were collected by a special plate with sloping walls directed to the middle (the shape of a up-turned umbrella) where the plate met the upper edge of the gravel filled container (Figure 9).

The samples from the aerobic and anaerobic zones were taken by the use of the vacuum pipette. The system of sampling in the anaerobic zone was simplified and consisted only of the inner plastic filter with an outlet pipe.

The quantity of wastes in the tanks was measured with a manometer. An open vertical pipe reaching the tank's bottom was placed in the tank. The compressed air, necessary to overcome the pressure of the column of wastes contained in the tanks, was introduced to that pipe. That pressure was measured by the liquid manometer. The liquid levels in the pressure gauge indicated the liquid level of the previously graduated tanks. Those tanks were scaled with an accuracy up to 15 dm^3 i.e. 0.3% at the least probable filling.

Applied Analytical Techniques

The treatment efficiency of the BLWRS was characterized by the analysis of samples of wastes, soil, and sludges.

1. Plastic filter
2. Outlet PCV pipe
3. Cover for PCV pipe nozzle
4. Pot filled with gravel
5. Collecting PCV plate
6. Vacuum pipette
7. Igelite suction conduit connecting pipette 6 with filter
8. Rubber fabric hose connecting pipette with vacuum system
9. Anaerobic zone
10. Aerobic zone

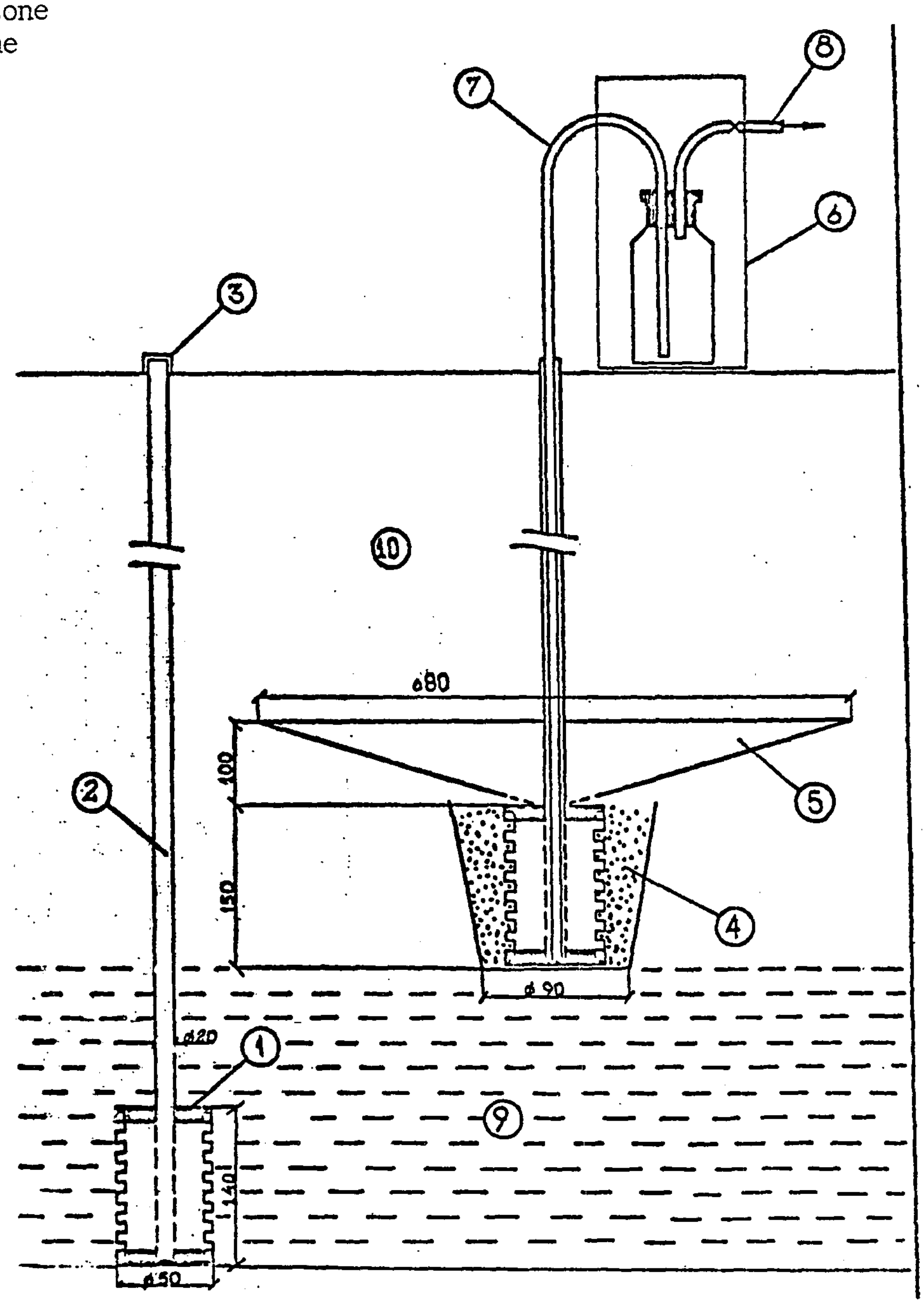

Figure 9. Liquid's sampling principle.

The waste samples were analyzed at different frequencies. Influents and effluents were analyzed for the TKN and COD content everyday. Testing the other parameters of influents and effluents as well as the analysis of the wastes from inside the BLWRS took place three times a week during the initial period of the investigation (July, August, September, and October 1979) and then once a week.

The wastes were analyzed for: SS, TKN, Ammonia Nitrogen ($N\text{-}NH_4$), Nitrate Nitrogen ($N\text{-}NO_3$), Nitrite Nitrogen ($N\text{-}NO_2$), TP, Ortho Phosphorus (ortho P), COD, BOD_5, Chlorine (Cl-), C_{org}, K, Na, Mg, Ca, Fe, Cu, Zn, Al, and Cd. The analysis of the wastes for SS, TKN, $N\text{-}NH_4$, $N\text{-}NO_3$, $N\text{-}NO_2$, TP, ortho P, COD, BOD_5, and Cl- were performed according to the procedures given by the American Public Health Association (1965) and Hermanowicz (1976). Organic carbon was analyzed by Total and Inorganic Carbon Analyzer - Model 915 produced by Beckman. The metal content of the wastes was determined by atomic absorption spectrophotometry using AA Spectrophotometer Model SP-2900 produced by Pye-Unicam. The electrothermal atomization was used for the samples of the low content of the tested metal. The samples with the relatively high metal concentration were analyzed in flame.

The determination of metal content in the wastes by atomic absorption spectrophotometry followed the preparation of waste samples by dry and wet mineralization according to the procedures given respectively by Pinta (1977) and Brzezinska (1978).

The samples of the BLWRS soil were taken three times, i.e. before starting the application of wastes and in the first and the second year of experiment. In the last two examples the samples were taken from 11 levels.

These soil samples were analyzed for TKN, Inorganic Carbon (C_{inorg}), C_{org}, TP, K, Na, Mg, Ca, Fe, Cu, Zn, Al, and Cd.

The determination of TKN, C_{inorg}, and C_{org} in the soil samples were, after they were dried at 105^oC, averaged, and finely ground in a porcelain mortar.

Determination of C_{inorg} was carried out according to the procedures given by Bundy (1978). The soil C_{org} was determined on an Elemental Analyzer produced by Perkin-Elmer - Model 240. TKN in soil samples was determined according to the procedures given by Bremner (1965).

The content of metals in the soil samples was analyzed on the AA Spectrophotometer SP-2900. The preparation of the soil samples for this type of analysis consisted of two stages. The first stage was analogous to the above described preparation of the soil samples for the TKN, C_{inorg}, and C_{org} determination. The second stage was based on the solubilization of the preliminary prepared soil samples with the use of the mixture of three acids according to the procedures recommended by Pinta (1977).

The soil samples prepared for the metal analysis were also used for the determination of TP. The detailed procedure for determination of TP is given by the American Public Health Association (1965).

The sludges from the BLWRS influents and effluents were also tested analytically. Carbon, nitrogen, and hydrogen content in the organic part of the sludge samples was determined on the P-E Analyzer Model 240. The sample which was introduced into the apparatus was prepared by centrifugation and drying the sludge at $105^{o}C$ to a constant weight, then it was finely ground in the porcelain mortar. Simultaneously with the elemental analysis, the same samples were tested for the content of VSS according to the method recommended by Hermanowicz (1977). The percent oxygen content of the soil air was determined with the use of membrane probe equipped with the automatic temperature compensation.

Preservation of Samples and Analytical Quality Control

Waste samples were preserved according to the methods recommended by Environmental Monitoring and Support Laboratory (1979) and Hermanowicz (1976).

To insure accuracy of the results, all analytical methods were checked periodically with standard samples. Moreover in each series, consisting of

26 samples at most, two blanks were run to check for contamination. The samples were rerun if the results differed considerable from the level of concentration characteristic for the tested sample and the period of investigations.

METEOROLOGICAL DATA

General Characteristics of Zulawy Climate

The study area was situated geographically at the south edge of Zulawy Wislane. The high instability of the weather condition from day to day and year to year is the characteristic quality of the Zulawy climate. The described area is under the definite influence of the air masses coming from the Atlantic Ocean. The relatively big annual amplitude and high average and absolute air temperatures and a considerable number of hot days created are characteristic of the Zulawy climate. The Zulawy is relatively warm and dry; the annual precipitation (based on many years of record) level is 600 mm.

The influence of the neighboring (Baltic) sea is expressed by a relatively high value of the average annual temperature oscillating around 7.5°C is evident in the Zulawy area.

The winter period with the average temperature below 0°C lasts for about 100 days. Such a long winter is caused by the masses of the cool air coming from the land.

The summer period ($T > 15^{\circ}C$) lasts at Zulawy for 86-99 days. The length of the farming period ($T > 0^{\circ}C$) ranges from 260 to 290 days per year.

The wind velocities in the area of Zulawy are considerably weaker than at the seaside with average annual values of 3-4 m/sec. The number of days with strong and very strong winds ($V \geq 10$ m/sec) ranges from 20-40 yearly.

The described area is within the range of the maritime - continental type of the atmospheric precipitation. This type of precipitation is characterized by a small annual amplitude, the occurence of the largest rainfall in July or August and by the predominance of the autumn precipitation over the fall. In July the sums of precipitation ranges between 80-90 mm. The daily totals are mostly equal to 1 to 5 mm and then 0.1 to 0.9 mm. These two totals cover 75% of the days with precipitation in the year. The number of the days with precipitation is in the range of 150-160 while the snow fall is noted during 40 days in the period from October to April. The snow cover is maintained for about 70 days.

From October to December the greatest pressure loss is observed here, and it is followed by the greatest variability of the weather. The following data illustrate how big the pressure changes can be; the lowest annual values of the atmospheric pressure change is in the range of 950-960 mbars while the highest level reached is 1040-1050 mbars.

Data characterizing the meteorological conditions existing at the BLWRS site in the period of investigations are shown in Table 6.

TABLE 6. METEOROLOGICAL DATA, CHARACTERISTIC FOR THE AREA OF THE EXPERIMENTAL BLWRS TIME PERIOD 1979 - 1980 (AVERAGE MONTHLY VALUES)

Month • Year	Precipitation (mm)	Evaporation (mm)	Soil Temp. at 5 cm Depth (°C)	Soil Temp. at 10 cm Depth (°C)	Soil Temp. at 20 cm Depth (°C)	Soil Temp. at 50 cm Depth (°C)	Average Daily Temperature (°C)
8.79	1.8	-	16.0	16.0	16.4	16.8	16.7
9.79	0.7	2.7	14.7	14.7	15.0	15.6	15.2
10.79	2.1	1.8	7.2	7.4	8.1	9.5	8.4
11.79	2.1	0.3	2.5	2.8	3.6	4.5	3.4
12.79	0.7	0.3	1.5	2.4	2.7	3.4	2.0
4.80	1.2	1.2	5.3	4.5	3.8	3.2	6.1
5.80	0.6	1.0	7.0	7.0	7.5	8.0	8.5
6.80	3.3	2.1	12.1	11.9	11.1	12.1	14.6
7.80	7.6	1.6	13.8	14.0	14.3	14.3	15.0
8.80	3.4	2.6	17.2	17.5	17.6	17.7	18.6
9.80	2.2	1.7	13.1	13.4	13.6	14.4	14.1
10.80	2.3	1.4	7.3	7.8	8.3	8.9	9.1
11.80	1.9	-	2.5	2.9	3.3	4.5	3.9
12.80	2.7	-	1.2	1.7	2.3	3.4	1.3

SECTION 5

RESULTS AND DISCUSSION

HYDRAULIC LOADING OF BLWRS

Observations at the BLWRS site were started on July 19, 1979, and were carried on until April 7, 1981; however, the 524 days which cover the period from July 24, 1979, i.e. the day when systematic waste feeding to BLWRS-12 was started, to December 31, 1980, i.e. the last day of applying wastes to BLWRS, constituted the experimental period. The investigations carried out before and after the above mentioned time period were of an indicatory nature. Figure 10 summarizes the operation until December 1980. Each line represents one of the four BLWRS sections. The solid bars above the horizontal line illustrate the amount of wastes applied each day. The open bars represent the amount of daily precipitation. The solid bars directly below the line represent the amount of effluent from each BLWRS section each day: applied and obtained figures are in millimeters of depth. The wastes were applied to both BLWRS beds until the moment when ponding started. Then the wastes feeding was stopped for the period necessary for the ponds to disappear. In 1979 for 128 days of system operation the wastes were fed to BLWRS-12 for 75 days and to BLWRS-34 for 77 days. In 1980 taking into consideration 260 operational days one can notice that the wastes were fed to BLWRS-12 for 208 days and to BLWRS-34 for 205 days. The operating period of 260 days in 1980 resulted from weather limitations. The breaks in operation of BLWRS were caused mostly by the necessity of drying out the overloaded system and in some cases by organization and technical difficulties. Values of the average daily hydraulic loading of BLWRS are presented in Table 7.

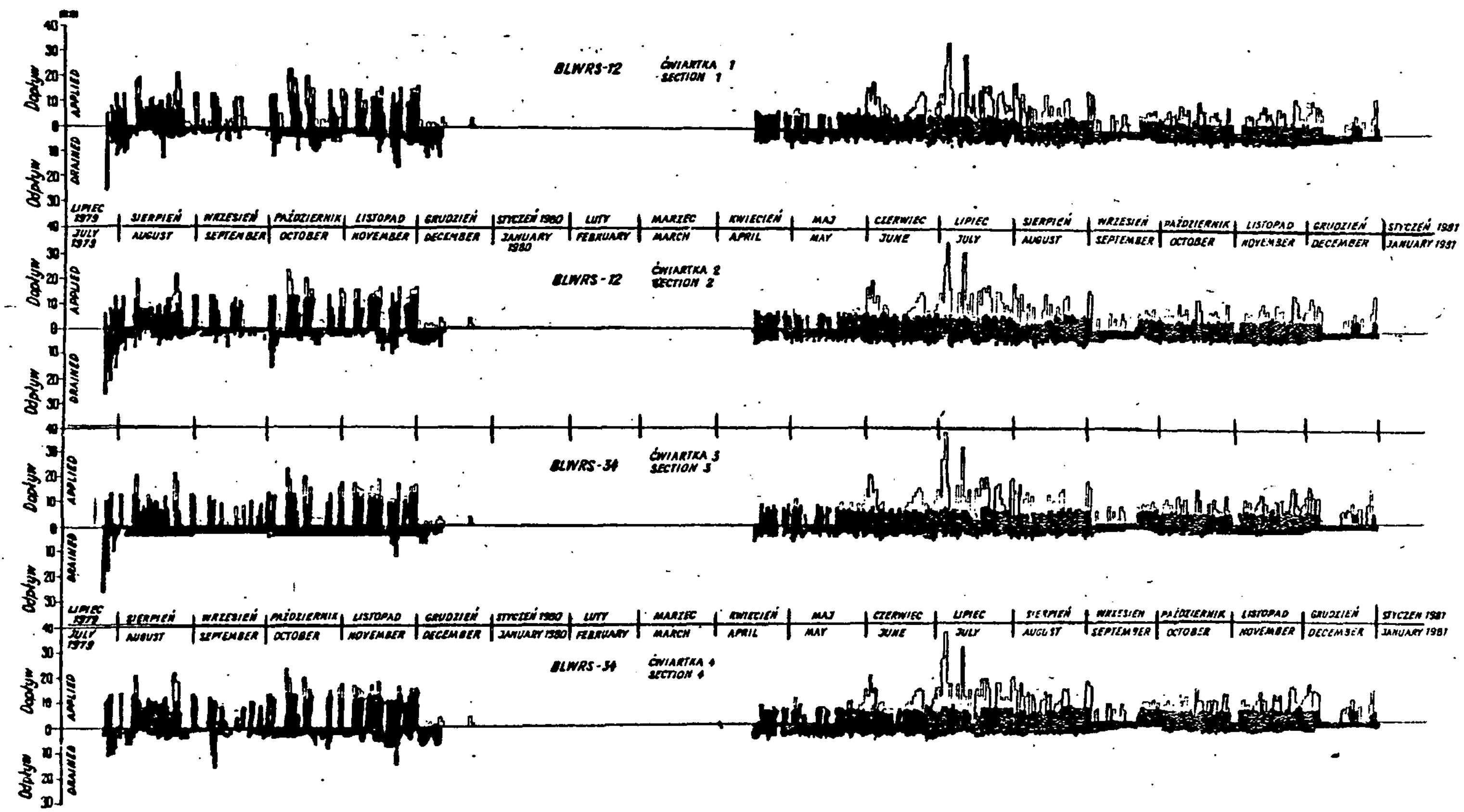

Figure 10. Chart showing the operation of BLWRS.

TABLE 7. HYDRAULIC LOADING OF BLWRS

	BLWRS-12		BLWRS-34	
	1979	1980	1979	1980
Applied wastes (mm)	715.6	1016.8	700.0	1005.0
Operational period (days)	128	260	128	260
Number of days during which the wastes were applied - operation days	75	208	77	205
Average daily dose of wastes in the operational period (mm)	5.6	3.9	5.5	3.9
Average daily dose of wastes for the operation days (mm)	9.5	4.9	9.1	4.9

As mentioned, the experimental period was equal to 524 days, yet during this time there was a four-month break which covers winter time because of the temperature drop below $0^{o}C$, and BLWRS operation was impossible. BLWRS operation diagrams differ among themselves mainly in regularity of the waste application and draining. In 1979 the largest possible amount of wastes, which could be accepted by the system, was applied to both BLWRS beds. The coincidence of the high hydraulic loading and the high average content of impurities in wastes applied caused the high loading of pollutants and hence ponds appearing very often at the surface of both BLWRS beds. In these cases it was necessary to employ the already mentioned stops in the waste application.

Profiting from the experience of the previous year in 1980, the daily dose of wastes was considerably reduced (as seen in Table 7). Simultaneously the quality of the applied wastes was improved; thanks to the better results of the preliminary treatment, BLWRS influent in 1980 was characterized by lower average concentrations of pollutants and a smaller range of the extreme concentrations than in 1979.

Water balance for both BLWRS beds in the periods of July 26, 1979, to November 30, 1979, and April 16, 1980 to December 31, 1980, are presented in Table 8.

Differences in the amount of wastes applied to BLWRS-12 and BLWRS-34 result from the differences in the pumps' output. Change of retention in the anaerobic zone was caused by damming up the wastes resulting from the development of slimy aggregates of microorganisms in the drainage system. This phenomenon occurred more intensively in the sections with energy inserts. The indicated balance differences averaged 13%, caused, supposingly, by the intensified evaporation during irrigation and only slightly exceeding the accuracy of the measurement of the applied waste volume, should be acknowledged as exceptionally favorable and reflect the tightness of BLWRS installation and BLWRS bottom.

CHARACTERISTIC OF WASTES APPLIED TO BLWRS

The applied wastes were characterized by average and extreme concentrations of the impurities presented in Table A-1 through A-4. Despite relatively low hydraulic loading the BLWRS received high pollutant loadings because of a high concentration of pollutants in the slurry applied to them. The data presented in Table 9 as well as in Figures A-1 through A-10 show the cumulative load of respective nutrients, leading to the conclusion that nutrient loads introduced to BLWRS in 1979 and in 1980 differ from each other considerably in the case of TP and COD. The comparison of the wastes applied to BLWRS-12 and BLWRS-34 in 1979 leads to the conclusion that despite the employment of the coagulation process, the preliminary treated wastes contain more impurities than in the case when only sedimentation is used. The reason for this seems to be the fact that wastes after sedimentation were collected in the influent's tank for 20 hours, so they represent the waste composition approximating the average daily waste composition, while the wastes after coagulation filled their tank during 15 minutes and always in the morning hours when the waste concentration from the pens was highest. In 1980 the process of coagulation was used very irregularly until it was completely given up. It resulted in a very low Al concentration in the wastes applied to BLWRS-12, on the average 6.9 mg/L in 1980 compared to

TABLE 8. BLWRS WATER BUDGET IN 1979 and 1980 (VALUES IN MM)

	1979				1980			
	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4
Applied wastes	715.6	715.6	700.0	700.0	1,016.8	1,016.8	1,005.0	1,005.0
Precipitation	215.0	215.0	215.0	215.0	672.0	672.0	672.0	672.0
Total influent	930.6	930.6	915.0	915.0	1,688.8	1,688.8	1,677.0	1,677.0
Drained wastes	565.6	572.5	524.7	498.3	1,032.7	1,023.9	1,030.2	1,016.8
Evaporation	263.0	263.0	263.0	263.0	348.4	348.4	348.4	348.4
Change of retention in BLWRS anaerobic zone	-	-	-	-	7.5	116.3	131.2	60.0
Potential total effluent	828.6	835.5	787.7	761.3	1,388.6	1,488.6	1,509.8	1,425.2
Losses	102.0	95.1	127.3	153.7	300.2	200.2	167.2	251.8
Percent of Losses	11.0	10.2	13.9	16.8	17.8	11.9	10.0	15.0

405.5 mg/L in 1979. However, simultaneously, thanks to the better work of the farm and the operators of the purification plant, the concentration of impurities in wastes decreased. Moreover, the daily amplitude of pollutants' concentrations was also reduced. Therefore, it could be expected that in 1980 both kinds of wastes introduced to BLWRS would not differ greatly among themselves, and this is so in the case of TKN, Total Suspended Solids (TSS), and TP. While the difference in the average annual COD concentration results from the application to BLWRS-34 (during the initial period i.e. from April 19-23, 1980) of the wastes of very high COD concentration, that at nearly identical volumes of the wastes applied to BLWRS-12 and BLWRS-34, gives the characteristic jump in the COD loading introduced to BLWRS-3 and BLWRS-4 (Figure A-4).

TABLE 9. LOADINGS OF IMPURITIES APPLIED TO BLWRS (VALUES EXPRESSED IN kg)

	BLWRS-12	BLWRS-34
	1979	
TN	758.4	656.0
TKN	667.4	615.0
COD	5,794.0	4,672.0
TP	325.6	222.0
	1980	
TN	712.6	748.6
TKN	656.2	697.4
COD	3,464.0	5,102.0
TP	91.6	111.6

The wastes introduced to BLWRS in 1980 contained on the average about eight times less SS than those used in 1979; this fact results in a decrease of the N_{org} fraction in TKN. In 1979 N_{org} constituted in the case of BLWRS-12 an average of 48.9% of the TKN and in the case of BLWRS-34, 42.5%, while in 1980 the average fraction of N_{org} in TKN in both kinds of wastes amounted to, respectively, 26.4% and 28.5%.

The result of better preliminary purification of wastes in 1980 can be observed as a decrease in COD concentration. In 1979 the wastes fed to BLWRS-12 were characterized by an average COD concentration equal to 9737 mg O_2/l, while in the case of BLWRS-34 this concentration was 9545 mg O_2/l. In 1980 the corresponding values were equal to 4844 mg O_2/l and 6488 mg O_2/l, respectively. The ratio of TKN:COD in 1979 was identical in the case of BLWRS-12 and BLWRS-34, 0.12, while in 1980 the TKN:COD ratio was equal to 0.19 for BLWRS-12 and 0.15 for BLWRS-34.

The amount of impurities fed to the BLWRS as calculated on a surface area basis is presented in Table 10.

TABLE 10. TOTAL LOADING RATE FOR BLWRS (VALUES EXPRESSED IN $\frac{kg}{m^2 \cdot day}$)

	BLWRS-12	BLWRS-34
	1979	
TN	0.0079	0.0068
TKN	0.0070	0.0064
COD	0.0604	0.0496
TP	0.0034	0.0023
	1980	
TN	0.0037	0.0038
TKN	0.0034	0.0036
COD	0.0178	0.0262
TP	0.0005	0.0006

Erickson (1974) used TN loading of 0.0063 $\frac{kg}{m^2 \cdot day}$ and COD loading equal to 0.041 $\frac{kg}{m^2 \cdot day}$ for these BLWRS studies.

CHARACTERISTICS OF BLWRS EFFLUENTS

Effluent quality indicates the way in which the treatment process in BLWRS is functioning. In the search to obtain the whole picture of the transformations, many different methods are presented in this section.

The average and extreme values of the concentrations of impurities in the effluents from each BLWRS section are presented in Tables A-5 though A-16. Division of the results into separate sets for each of two years of experiment the increase of pollutants' concentrations in the second year of operation. To enhance those differences the average annual concentrations of the selected nitrogen forms and COD in BLWRS effluents are presented in Table 11. Differences in TN content of BLWRS-1 and BLWRS-4 effluents in 1979 are negligible in comparison to such differences in 1980. This shows more clearly the influence of the additional energy source in the second year of BLWeS operation. In 1980 the level of TN in the effluents increased about 50% in relation to the 1979 concentrations for BLWRS without the energy source (1 and 4) in the forms of oxidized nitrogen and for BLWRS 2 and 3 as TKN. The increase of TN wasn't caused by the higher loading or the higher concentration of nitrogen in the slurry fed to BLWRS in 1980 which can be noticed from the comparison of Tables A-1 to A-3 and A-2 to A-4. The slower nitrification and denitrification rates as well as the smaller losses of ammonia at the moment of waste sprinkling can be the other causes of TN increase. The last supposition is denied by the increase of the $N\text{-}NH_4$ fraction in TKN in the wastes fed to BLWRS. Average annual concentrations of $N\text{-}NH_4$ and $N\text{-}NH_4$ fraction in TKN in the raw wastes during the study are characterized in Table 12. The discussed increase of $N\text{-}NH_4$ fraction appeared also in the BLWRS effluents. Average annual $N\text{-}NH_4$ fraction in TKN for the BLWRS effluents amounted during the study period to the values shown in Table 13. The slower rate of the nitrification process could be caused by the decrease in the mineralization rate. This last supposition is confirmed by the decrease of the results of the waste purification from N_{org} which was observed on BLWRS in 1980 in comparison with 1979 as observed in Table 14.

TABLE 11. AVERAGE ANNUAL CONCENTRATIONS OF THE SELECTED NITROGEN FORMS AND COD IN BLWRS EFFLUENTS EXPRESSED IN mg/1

Parameter	1979				1980			
	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4
$N\text{-}NH_4$	57.5	80.9	62.6	44.8	107.5	195.5	213.0	120.0
TKN	104.6	155.8	93.5	80.3	121.4	226.1	246.6	115.9
N_{oxid}	112.6	92.6	104.5	108.6	216.8	91.0	107.1	160.7
TN	217.2	248.4	198.0	188.9	338.2	317.1	353.7	276.6
COD	281.2	551.2	291.7	260.8	299.0	470.4	443.8	269.7

TABLE 12. AVERAGE ANNUAL N-NH_4 CONCENTRATIONS IN RAW WASTES

Year	BLWRS	N-NH_4 (mg/1)	N-NH_4/TKN (%)
1979	12	535.6	50.5
	34	548.0	57.9
1980	12	625.5	71.7
	34	677.7	71.7

TABLE 13. AVERAGE ANNUAL N-NH_4 CONCENTRATIONS IN EFFLUENTS

	1979	1980
BLWRS-1	71.8%	78.6%
BLWRS-2	68.9%	84.2%
BLWRS-3	78.0%	82.5%
BLWRS-4	54.8%	78.6%

TABLE 14. PERCENT OF ORGANIC NITROGEN REMOVAL

	1979	1980
BLWRS-1	90.0%	85.1%
BLWRS-2	83.9%	79.7%
BLWRS-3	92.8%	76.9%
BLWRS-4	87.7%	86.9%

The inhibition of the rate of mineralization, nitrification and denitrification processes in the second year of experiment couldn't be caused by the inhibiting activity of the concentration of H ions because both in 1979 and in 1980 pH of raw wastes and effluents was maintained in the range of 6.5 - 8.5, considered as the optimum pH range for these processes (Alexander, 1965; Clayfield, 1974). Moreover, the average and extreme annual pH values in BLWRS effluents and influents in 1979 and 1980 were nearly identical.

The slower rate of the mineralization and nitrification processes which is followed by the decrease in denitrification rate was, therefore, the cause of increase of TN concentration in BLWRS effluents in 1980. This statement is confirmed also by the decrease of the results of TKN and TN removal from the wastes which was observed on BLWRS in 1980 compared with 1979 (Table 17).

The comparison of the concentrations of nitrogen forms and COD in the effluents from the BLWRS section equipped in the additional energy source with the corresponding values in the effluents from the sections without energy insert indicates that. However, the addition of this kind of energy source which constituted the sludges, separated mechanically from the slurry, accelerated process of denitrification, which was reflected by the decrease in the oxidized nitrogen forms in BLWRS-2 and BLWRS-3 effluents in comparison with concentrations of these forms in BLWRS-1 and BLWRS-4 effluents, but simultaneously, at the same degree it caused TKN to be washed out. Moreover, because of the washing out of carbon compounds from energy insert, the concentration of COD in BLWRS-2 and -3 effluents increased.

The average concentration of TP, which in 1979 maintained in all the effluents at the same level ranging from 1.5 mg/1 to 2.7 mg/1, increased considerably in 1980 and oscillated from 5.9 mg/1 in BLWRS-1 effluent through 6.7 mg/1 in BLWRS-2 and -3 effluents to a 10.8 mg/1 in BLWRS-4 effluent. The increase of the average annual concentration of TP in BLWRS-4 effluent was caused by a considerable jump in the TP content that was observed in December 1980 when the average monthly TP concentration in the effluent rose to 74.7 mg/1 in comparison with the average TP concentration for the previous period, which equalled only 4.7 mg/1. The increase of TP concentration was caused by the high concentration of SS which amounted to 958.7 mg/l for the month of December 1980, in comparison to the mean value for the previous period (April 1980 to November 1980) which was 42.0 mg/l. The similar symptom was observed in the case of BLWRS-1, -2, and -3 effluents. Average monthly TP concentrations in these effluents in December 1980 were respectively 35.8, 29.0, and 32.0 mg/l, while during the whole period of 1980 which proceeded December, TP concentration in the effluents from BLWRS-1, BLWRS-2, and BLWRS-3 were, respectively, 2.9, 4.4, and 4.1 mg/l. The rise in TP concentration resulted from the increased amount of SS which were torn away from the pipe at the time of sampling because of the change in the sampling technique, which was used in the winter months, i.e. when there was no feeding of the BLWRS with slurry. The effluent was so low that samples were taken from the discharge pipes with a siphon device.

Table 15 as well as Figures A-11 through A-28, shows the accumulation of the loads of the particular nutrients in the course of the year, indicating the considerable increase of the loadings of impurities in BLWRS effluents in 1980 compared with 1979.

The comparison of the loadings of impurities introduced to and drained away from BLWRS, during the experimental period leads to the conclusion about the reduction of the efficiency of the waste purification in BLWRS in 1980. A similar conclusion results from the review of the removal rates of some nutrients in BLWRS which values are presented in Table 16.

It should be added that at the calculated rates of impurities removal, the following periods were taken into consideration: July 26, 1979 to November 30, 1979 and April 16, 1980 to November 30, 1980, while December was disregarded as the month which differed too greatly from the rest of the months. The same experimental period, i.e. the one in which December 1979 and December 1980 were excluded, was taken into consideration while calculating parameters of the equations describing the relationship between the loading of removed impurities and the loading of the applied impurities, as well as during calculations of the efficiency of the waste purification in BLWRS.

TABLE 15. LOADINGS OF IMPURITIES DRAINED FROM BLWRS DURING THE EXPERIMENTAL PERIOD (MEAN VALUES EXPRESSED IN $\frac{kg}{m^2 \cdot day}$)

	1979				1980			
Parameter	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4
TKN	$5.63x10^{-4}$	$7.55x10^{-4}$	$3.42x10^{-4}$	$2.97x10^{-4}$	$5.80x10^{-4}$	$1.00x10^{-3}$	$1.07x10^{-3}$	$5.32x10^{-4}$
TN	$1.23x10^{-3}$	$1.04x10^{-3}$	$7.83x10^{-4}$	$8.92x10^{-4}$	$1.51x10^{-3}$	$1.44x10^{-3}$	$1.64x10^{-3}$	$1.20x10^{-3}$
COD	$1.43x10^{-3}$	$2.26x10^{-3}$	$1.02x10^{-3}$	$8.52x10^{-4}$	$1.37x10^{-3}$	$2.09x10^{-3}$	$1.94x10^{-3}$	$1.30x10^{-3}$
TP	$1.01x10^{-5}$	$1.62x10^{-5}$	$9.38x10^{-6}$	$8.38x10^{-6}$	$1.94x10^{-5}$	$2.40x10^{-5}$	$2.50x10^{-5}$	$3.93x10^{-5}$

TABLE 16. THE RATES OF REMOVAL OF IMPURITIES IN BLWRS (MEAN ANNUAL VALUES EXPRESSED IN kg/day)

	1979				1980			
Parameter	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4	BLWRS-1	BLWRS-2	BLWRS-3	BLWRS-4
TKN	2.53	2.45	2.37	2.39	1.21	1.05	1.11	1.31
TN	2.59	2.62	2.29	2.27	0.98	1.02	1.00	1.16
COD	22.95	22.67	18.87	18.97	7.03	6.74	10.41	10.65
TP	1.27	1.27	0.87	0.87	0.19	0.19	0.23	0.23

The efficiency of animal waste purification in BLWRS is shown in Table 17.

The efficiencies of slurry purification of BLWRS studied by Erickson (1974) are depicted in Table 18.

TABLE 18. REMOVAL EFFICIENCIES FOR MICHIGAN STATE UNIVERSITY BLWRS (ERICKSON 1974)

Section With Grain Energy Insert		Section Without Energy Insert	
TKN	86.9%	TKN	99.8%
TN	90.0%	TN	76.6%
COD	25.7%	COD	92.4%
TP	99.8%	TP	99.9%

Data analysis indicates that we obtained slightly worse results in TN and TKN removal while better effects as far as COD removals are concerned.

The comparison of both, the level of concentration in the case of such indicators as TKN, TN, and COD (excluding TP) in BLWRS effluents as well as the efficiency of waste purification shows that BLWRS-34 fed with wastes without aluminium sulphate constituted the part of the experimental BLWRS which worked best. BLWRS-4 appeared to be the best section, both in the whole experimental period and each year. The introduction of the additional energy source didn't change the effect of the TN removal from the wastes; however, it reduced the efficiency of the removal of carbon compounds and TKN. This fact makes the use of sludges as the additional energy source for the process of denitrification in BLWRS undesirable.

The relationship between monthly applied and removed loadings of TKN, TN, COD, and TP during the experiment and for all BLWRS sections together are presented in Figures A-29 through A-32. In all the cases this relationship can be described by the straight line equation which parameters are as follows:

TABLE 17. EFFECT OF WASTE PURIFICATION IN BLWRS (VALUES EXPRESSED IN %)

	1979				1980				1979 + 1980			
Parameter	BLWRS 1	BLWRS 2	BLWRS 3	BLWRS 4	BLWRS 1	BLWRS 2	BLWRS 3	BLWRS 4	BLWRS 1	BLWRS 2	BLWRS 3	BLWRS 4
TKN	93.9	91.0	95.5	96.4	86.2	74.9	75.4	89.0	90.1	83.1	85.0	92.5
TN	87.4	88.4	89.4	89.4	65.1	67.6	64.2	74.2	76.8	78.5	76.3	81.5
COD	98.2	97.0	98.3	98.8	94.3	90.4	94.5	96.8	96.8	94.6	96.3	97.8
TP	99.8	99.6	99.6	99.7	97.7	96.6	97.3	98.1	99.3	99.0	98.9	99.1

Parameters of the equation are:

$$y = b + ax \qquad (3)$$

where: y - applied loading, kg
x - removed loading, kg

As shown in the results from Table 19, the correlation between removed and applied loadings is significant at the probability level of making the mistake ≤ 0.001. During the whole experimental period, in the case of all mentioned nutrients and for all BLWRS sections, the removed loading of impurities increased together with the increase of the applied loading of impurities. As it results from the numerical values of a and b constants (shown in Table 19) in the case of all four indicators i.e.: TKN, TN, COD, and TP at the invesitgated loading range, the degree of purification increased together with the load. It resulted, of course, from the higher effects of purification obtained during the first year of BLWRS operation, despite applying at this time higher loadings than in the following year.

TABLE 19. CORRELATION BETWEEN REMOVED AND APPLIED LOADING

Nutrient	N[1/]	b	a	r Correlation Coefficient	1 - α Correlation Probability	r_t Theoretical Correlation Coefficient for α = 0.001
TKN	50	-6.8787	1.0093	0.9903	0.999	0.449
TN	50	-8.9223	0.9533	0.9866	0.999	0.449
COD	50	-13.8673	1.0040	0.9994	0.999	0.449
TP	52	-0.1369	1.0004	1.0000	0.999	0.443

[1/] Number of pairs of monthly applied and removed loadings of impurities calculated for 4 BLWRS sections and 13 months of experiment.

TRANSFORMATIONS OF IMPURITIES IN BLWRS VERTICAL PROFILE

Basic Relationships

Fixation, decomposition, and elution of applied impurities and of generated products of transformations take place in the course of filtering the wastes through a BLWRS bed, as a result of many different physical, chemical, and biological processes. Description of the kinetics of these transformations for the respective constituents or indicators of pollution should constitute the significant argument of the presented results. As the section dealing with kinetics will show, the results didn't meet the expectations. Therefore, this chapter, which was first foreseen as definitely descriptive, had to be transformed into a form containing the trial of the mathematical interpretation.

The applied range of the transformations' control made possible the analysis of only the choosen indicators, as the elements changed with the increase of the percolation pathway "m", i.e. the thickness of the bed. These analyzed indicators were as follows:

- COD transformation could be considered as the process of mineralization of organic substances but that is not exact because COD, as determined in the nonfilter samples, includes also a solid and colloidal fraction; therefore, the indicated transformations may not necessarily have been caused by the decomposition of the organic substances. However, if we accept that the results collected during the longer period of investigations, characterize some already stabilized state of equilibrium, COD transformations can be treated as the effect of mineralization; exclusively.
- N_{org}, on the basis of the same principle, through its losses, characterizes the process of ammonification.
- TKN characterizes, through its losses, the nitrification process.
- TN describes in the same way the process of denitrification.
- TP describes the process of its elimination.
- The change in the content of SS supplements the analyzed processes.

The above mentioned processes are presented in the form of definite dependence on the thickness of the bed, which can be treated as the time equivalent if the kinetic approach to the transformations is concerned. The mean values for both BLWRS from the periods of 1979 and 1980 constituted the results, which were considered not in the physical but in the mathematical description. The arithmetic mean from each BLWRS and each year entered the population of given level "m" as the degree of freedom. These results were referred to the correspondent thicknesses from the six investigated ones i.e.: 0, 30, 80, 140, 160, and 180 cm. Considering the logarithmic relationships instead of m = 0, the close but bigger than zero value was introduced. Three of the given levels are situated in the anaerobic zone, but the investigations on the correlation sigificance indicated their compactness with the aerobic zone.

The tested forms of the mathematic relationships indicated the highest significance for the following equation:

$$\frac{C_m}{C_o} = b\, m^a \qquad (4)$$

where: C_o and C_m initial concentration and concentration on the "m" level, a and b - equation parameters given in Table 20.

The presented equations and parameters constitute the basis for the further considerations and calculations.

TABLE 20. PARAMETERS OF EQUATION 4 FOR THE RESPECTIVE INDICATORS

Indicator	a	b	r	T_{exp}	T_t $\alpha = 0.001$
COD	-0.6286	1.1748	-0.9248	11.4	3.73
N_{org}	-0.4971	1.1947	-0.8476	7.49	3.73
TKN	-0.4492	1.1850	-0.8976	9.55	3.73
N_{oxid}	+0.6386	0.8596	+0.9633	13.43	4.14
TN	-0.2475	1.0323	-0.9229	10.30	3.73
TP	-0.7686	1.3141	-0.8730	8.40	3.73
SS	-0.6182	0.9152	-0.7697	5.65	3.73

Presenting these considerations, we are conscious of the imperfection of the statistical interpretation; however, this interpretation was the only one that could be obtained, and the one which enables a relatively simple reproduction of the transformations picture.

The form of equations limits their application to m > 1.5 cm. Therefore, the discussed equations do not include the transformations on the surface and in the upper 1.5 cm layer of BLWRS bed.

COD - Organic Carbon Relation

Oxidation of organic compounds to intermediate products or considerable oxidized final products should cause the decrease of the COD:C_{org} ratio. The above statement was investigated for each BLWRS level.

Pairs for which the COD:C_{org} ratio wasn't in the range of 1.5 - 5.3, i.e. these results which were charged with random error, were eliminated from the processed data set. The rest of the data went through linear regression and the parameters in Table 21 were obtained for the correlation equation:

$$\text{Correlation COD} = a\ C_{org} + b \qquad (5)$$

TABLE 21. PARAMETERS FOR COD:C_{org} CORRELATION EQUATION

Level m	N	COD g/1	C_{org} g/1	a	b	r
0	29	7.2429	2.5387	3.948	-2.781	0.9401
30	15	1.1503	0.4023	2.810	0.020	0.8624
80	31	0.6921	0.2381	3.474	0.135	0.8819
140	113	0.4046	0.1672	2.420	0.000	0.8882
160	116	0.4111	0.1665	2.432	0.006	0.8704
180	67	0.3227	0.1421	1.846	0.060	0.8881
Σ	371	0.9806	0.3632	3.187	-0.177	0.9580
Σ - 0	342	0.4495	0.1788	2.745	-0.041	0.8819

All above mentioned relationships are statistically significant for $\alpha = 0.001$. The fact that results for "0" level do not fit the rest of the data is clearly shown in Table 21. It is quite natural, as in the wastes applied to BLWRS surface are also substances without carbon, which undergo oxidation in the conditions of COD determination and organic sustances which are oxidized very easily or they are strained out on the BLWRS surface. Therefore, these substances do not appear in the samples taken within the BLWRS at lower levels. However, value "b" is statistically insignificant and can be omitted. The value of regression coefficient decreases considerably with the increase of the degree of elimination of impurities or with the oxidation degree.

The whole data set, with the high correlation coefficient, can also be expressed by a single equation, which with the omission of the insignificant constant "b" gives a straight line going through the origin of coordinates and with a slope coefficient equal to 3.0987.

Quantitative Changes of Organic Substance in Solid Phase

Depositing of the solid organic substance (VSS) takes place in BLWRS as the result of application of impurities and their decomposition. It is expressed by the increase in the biomass of microorganisms and depositing of SS carried in by the wastes (VSS_0). However, the endogenous decomposition of the biomass and VSS_0 takes place in parallel to the other processes. This complex of processes leads to definite states of equilibrium at the respective BLWRS levels. Parameters, which form this state, were determined using equations given in the proceeding sections as well as the results of the transformations in the composition of soil used in the BLWRS.

The scatter of the results of VSS transformations in the vertical profile of BLWRS soil, taken from the direct measurements, is so big that they are not as confident as TKN results. That is why VSS was calculated from TKN, assuming that VSS = TKN : 0.124, which corresponds to 12.4% of nitrogen content in the suspended solids.

TKN content in BLWRS vertical profile in relation to the thickness (m) through which the wastes flow, can be described for the mean values from the whole period of BLWRS operation by the equation with a correlation coefficient $r = 0.9513$, $T_{exp} = 9.26$ while $T_t = 5.04$ for $\alpha = 0.001$.

This equation after recalculating into VSS gives the expression:

$$VSS = 35{,}286\ m^{-0.8328} \quad \left[\frac{mg}{dm^3}\right] \tag{6}$$

where: m - thickness, cm.

Looking for the correlation between the value of the increase of VSS in the BLWRS soil and the removed COD load resulted in the following relationship:

$$\frac{-\Delta\ VSS}{VSS\ .\ t} = \frac{\Delta\ VSS_o}{VSS\ .\ t} + a\ .\ \frac{\Delta\ COD - 1.33\ \Delta\ VSS_o}{VSS\ .\ t} - b\ \left[day^{-1}\right] \tag{7}$$

where:

$a = 0.49$

$b = 0.00229$

$r = 0.999$

$T_{exp} = 132.2$

$T_t = 5.04$

Resulting from this equation the rise of the unit biomass growth with the increase of the depth of BLWRS bed and the decrease of the unit COD loss is caused, probably, by the variable rate of decomposition and depositing of the suspended solids carried in by the wastes (VSS_o).

Analogical correlation related to Δ COD of the unfiltered samples without taking into consideration VSS_o, indicates the invariability of the unit VSS growth in the bed along the whole vertical BLWRS profile with the accuracy reaching the third place. Simultaneously, after the period of BLWRS adaptation, the increase of the VSS in the bed isn't observed, that indicates the development of the state of equilibrium in the process of the biomass synthesis, depositing and biochemical oxidation of the organic matter.

Transformations of Nitrogen Compounds

Discussion of the parameters of equation 4 for N_{org}, TKN, and TN leads to the conclusion that TN losses proceed with lower velocity but in a way similar to the losses of other nitrogen forms. Assuming that TN losses result from denitrification, this course of the process is hardly probable as it is hardly probable that intensive nitrification takes place in the upper 30 cm BLWRS layer at the applied loadings. Perhaps ammonia losses constitute the dominant factor here. Unfortunately the determinations of initial concentrations on the surface of BLWRS were not conducted. In each case TN losses accompany proportionally the processes of mineralization and nitrification. The N balance expressed, for the particular forms, as the percentage of the initial amount of TN are presented in Table 22. This balance was prepared on the basis of mathematical relations up to 2.0 m of thickness and zero values obtained from the data characterizing wastes applied to BLWRS.

TABLE 22. NITROGEN BALANCE WITHIN THE BLWRS EXPRESSED AS A PERCENTAGE OF THE INITIAL TN

Thickness, cm	0	10	50	100	200
TN	100.0	58.4	39.2	33.0	27.8
N_{org}	43.5	16.5	7.4	5.3	3.7
$N\text{-}NH_4$	56.0	25.4	12.9	9.6	7.2
TKN	99.5	41.9	20.3	14.9	10.9
$N\text{-}NO_2 + N\text{-}NO_3 = N_{oxid}$	0.5	3.7	10.5	16.3	25.3
$\Delta N = TN - (TKN + N_{oxid})$	0.0	12.8	8.4	1.8	-9.4
$N_{ammonif} = \Delta N_{org}$	0.0	27.0	36.1	38.2	39.8
N_{nitr} I = Δ TKN	0.0	57.6	79.2	84.6	88.6
N_{denitr} I = Δ TN	0.0	41.6	60.6	67.0	72.2

Δ N indicated in the balance is caused by the inaccuracy of the mathematical description of TN, TKN, and N_{oxid} transformations. The presented N balance confirms the conclusions which were previously brought forward.

Transformations of Phosphorus Compounds

The phosphorus compounds applied to the BLWRS in the form of organic and mineral substances were removed up to a very high degree. The degree of TP removal increases with the increase of BLWRS loading; in 1979 it exceeded 99%, and in 1980 it was reduced to 94% -96%. These effects were calculated from the balance of monthly loadings. The relationship between the removed and applied loads can be expressed by the following equation:

$$L_r = 1.0004 \quad L_{app} - 0.1369 \tag{8}$$

with the very high correlation coefficient equal to 1.000.

The transformation of phosphorus compounds, through P fixation in the synthesis of the cellar mass, oxidation to phosphates and their fixation as well as adsorption in BLWRS bed caused the reduction of P concentration in BLWRS vertical profile. This includes the concentration of TP in the liquid phases as well as the concentration of this element in BLWRS soil.

The relationship between these two parameters on the basis of laboratory investigations can be expressed by the Freundlich isotherm according to Erickson (1974). In our investigations, conducted under field conditions, such concentration of the liquid samples in the vertical profile, as it was in the case of soil samples, was impossible. This is why, as we wanted to test the above mentioned relationship, phosphorus concentrations in liquid (c) at the corresponding levels of BLWRS soil were extrapolated, based on the statistically adjusted (with the support of a regression equation) results from the five levels and for the period of the month prior to the day of the soil sampling.

The following equation was applied here:

$$\lg C = b = am \tag{9}$$

where: $c - \frac{mg}{l}$; m - cm

with the results shown in Table 23.

TABLE 23. RESULTS OF EQUATION lgC = b = am FOR P TRANSFORMATION

Location	r	T_{exp}	T_t $\alpha = 0.001$	a	b	N
BLWRS-12-79	-0.9502	17.51	3.65	-0.0107	2.1804	35
BLWRS-34-79	-0.9408	15.20	3.65	-0.0097	2.3729	32
BLWRS-12-80	-0.9637	20.09	3.65	-0.0101	2.0188	33
BLWRS-34-80	-0.9403	14.88	3.65	-0.0092	1.9899	31

These equations are not very good in the description of the transformations occurring in the upper 25 cm layer of BLWRS soil, in which the experimental concentration gradient is higher than the calculated one.

Data adjusted in the described way were applied to:

Langmuir isotherm

$$\frac{1}{x} = \frac{1}{x_m} + \frac{1}{bx_m c} \quad (10)$$

where: x - P concentration in soil, ppm

x_m - maximum P concentration for the given soil, ppm

and Freundlich isotherm

$$\lg x = \lg k + \frac{1}{n} \lg c \quad (11)$$

where: c - P concentration in wastes, mg/l

b, k, n - constants

gave the following results respectively as seen in Table 24.

TABLE 24. RESULTS OF LANGMUIR AND FREUNDLICH ISOTHERM ON P DATA

r	T_{exp}	T_t $\alpha = 0.001$	N		
0.6461	4.13	3.65	33	x_m = 246.6	b = 0.0367
0.6867	5.26	3.65	33	k = 28.87	n = 2.3981

Analyzing the data in Table 24, one can see a slightly better approximation of the Freundlich isotherm. BLWRS-34 data from 1980 were omitted in these calculations as they determined the distribution of phosphorus in the soil samples from BLWRS vertical profile in the completely random way, and conducting the interpretation of these results is impossible.

On the basis of phosphorus content in BLWRS soil, determined as the weighed mean of the depths, the loading of TP retained in BLWRS was calculated and then these values were compared with the TP loadings removed from wastes during each year of BLWRS operation. These comparisons are shown in Table 25.

TABLE 25. COMPARISON OF TP LOADINGS AND TP REMOVED IN BLWRS

BLWRS	TP Removed 1979	TP Found 1979	TP Removed 1980	TP Found 1980	TP Removed Total	TP Found Total
	kg					
1	162.4	108.4	44.1	77.9	206.5	186.3
2	162.1	87.3	43.7	77.8	205.8	165.1
3	110.8	83.8	53.6	116.8	164.4	200.6
4	110.8	136.9	52.4	58.0	163.2	194.9
Total	546.1	416.4	193.8	330.5	739.9	746.9

Special satisfaction can be found in comparing total loadings for the whole experimental period. However, it should be realized that this compatibility is caused to a higher degree by chance, rather than by the balance precision. The results show clearly enough by comparing the rest of the pairs of values, that the correlation is not statistically signficant:

$$(T_{exp} = 0.94;\ T_{t \atop \alpha = 0.05} = 2.45). \qquad (12)$$

KINETICS OF POLLUTANTS' TRANSFORMATIONS IN BLWRS VERTICAL PROFILE

Transformations of N and C compounds in vertical BLWRS profile were described by matching the suitable mathematical model from the ones most frequently applied to these transformations. Ten equations, describing the processes of waste purification, therefore processes resembling the ones which were investigated in BLWRS, were selected from the accessible literature data. Time was replaced by the thickness in all equations. The analyzed equations had the following form:

$$C_m = C_o \cdot k \cdot m \tag{13}$$

$$C_m = C_o \cdot e^{-km} \tag{14}$$

$$C_m = C_o \cdot b \cdot m \tag{15}$$

$$C_m = \frac{C_o}{1 + km} \tag{16}$$

$$\frac{m \cdot F}{(C_o - C_m) \cdot Q} = \frac{1}{a} + \frac{b}{a} \cdot \left(\frac{2}{C_o + C_m}\right) \tag{17}$$

$$\frac{(C_o - C_m) \cdot Q}{F \cdot m} = a.\left(\frac{C_o \cdot Q}{F \cdot m}\right)^b \tag{18}$$

$$\frac{(C_o - C_m) \cdot Q}{m \cdot F \cdot \gamma} = \left[z + k_1 \cdot T + \frac{k_2 \cdot C_x \cdot Q}{m \cdot F \cdot \gamma} + K_3 \cdot \lg\left(\frac{C_\gamma \cdot Q}{m \cdot F \cdot \gamma}\right) \right] \cdot D \tag{19}$$

$$D = -2.51 + 1.85 \lg \frac{C_c}{C_x}$$

$$\frac{(C_o - C_m) \cdot Q}{m \cdot F \cdot \gamma} = z' + \frac{k_1' \cdot T \cdot C_\gamma \cdot Q}{m \cdot F \cdot \gamma} + k_2' \lg\left(\frac{C_\gamma \cdot Q}{m \cdot F \cdot \gamma}\right) + k_3' \cdot \lg\left(\frac{C_z \cdot Q}{m \cdot F \cdot \gamma}\right) \tag{20}$$

$$C_m = C_o' \cdot e^{-km} \qquad (21)$$

$$C_O' = C_{ONK} - 0.043 \cdot C_{OC}$$

$$C_m = C_O \cdot e^{-kmC_c} \qquad (22)$$

In the above mentioned ten equations the following symbols were used:

C_o - concentration of the investigated parameter in the wastes applied to BLWRS, mg/l

C_m - concentration of the investigated parameter after going through the layer of the "m" thickness, mg/l

m - thickness, cm

k - reaction rate constant, cm^{-1}

F - BLWRS surface = $750 \cdot 10^4$ cm^2

Q - amount of wastes applied to BLWRS, $1 \cdot day^{-1}$

a,b,n - equations' parameters

γ - bulk density of BLWRS soil = $1.55 \cdot 10^{-3}$ $kg.cm^{-3}$

z	=	$8.92 \cdot 10^{-1}$	z'	=	$4.64 \cdot 10^{0}$
k_1	=	$2.16 \cdot 10^{-3}$	k_1'	=	$1.62 \cdot 10^{-3}$
k_2	=	$2.70 \cdot 10^{-2}$	k_2'	=	$2.38 \cdot 10^{-1}$
k_3	=	$3.92 \cdot 10^{-1}$	k_3'	=	$-2.51 \cdot 10^{0}$

Values z, k_1, k_2, k_3, z', k_1', k_2', and k_3' came from the computer model of simulation of dynamic bio-physicochemical processes occurring in soil, developed by Dutt et al. (1972).

T - average temperature for the given thickness, ^oC

C_x - N_{org} average concentration for the given thickness, mg/l

C_y - $N\text{-}NH_4$ average concentration for the given thickness, mg/l

C_z - $N\text{-}NO_3$ average concentration for the given thickness, mg/l

C_c - average concentration of C_{org} for the given thickness, mg/l

Average concentration of the analyzed parameters for the given thickness was calculated by taking into consideration the percentage fraction of each zone.

C_{OTKN} - TKN concentration in wastes applied to BLWRS mg/l
C_{OC} - C_{org} concentration in wastes fed to BLWRS mg/l.

Equations 13 - 16 are characteristic for the kinetics of the process of biological treatment of waste. The relationship between the process rate and time was approximated here respectively by a pseudo-zero-order, pseudo-first-order, and pseudo-second-order reaction, with the use of the generally applied equations. Equation 17 is the form of Michaelis-Menten (Michaelis-Menten, 1913) relationship in the development of Lineweaver-Burk (Dawes, 1967), describing kinetics of enzymatic reactions. Equation 18 expresses the Haseltine function (Haseltine, 1957), defining the relation between the removed and applied loading. Equations 19 and 20 are the equations of ammonification and nitrification developed from the computer model of the simulation of dynamic bio-physicochemical processes occurring in soil and given by R. Dutt et al. (1972). Equations 21 and 22 are the modifications of equation characteristic for pseudo-first-order reaction; in Equation 21 the influence of C/N ratio (in the waste applied to BLWRS) on the rate of nitrification was taken into account. Here the relationships given by Reddy et al. (1979) were followed. In Equation 22, based on the work of Rolston et al. (1980), the influence of the concentration of C_{org}, contained in the wastes, on the nitrification rate was taken into account.

Equations 13 - 18 were checked for the following five parameters: TKN, N_{org}, TN, COD, and C_{org}. Equation 19 was applied only for the transformations of N_{org}. Equations 20 and 21 were employed exclusively for TKN transformations, and Equation 22 served for describing the process of denitrification as the loss of TN.

Transformations of N and C forms of pollutants in BLWRS vertical profile were described based on the four control levels in the aerobic zone i.e. on the depth of 0, 0.3, 0.8, and 1.2 m, while the concentration of the investigated compounds on the depth of 1.4 m, therefore already in the saturated zone, but from the section without additional energy source, were assumed to represent the concentration of the investigated parameters on the 1.2 m level. The mathematical interpretation of pollutants' transformations occurring in the BLWRS anaerobic zone was impossible because there was not enough controlled levels in the saturated part of the vertical profile.

The usefulness of the above mentioned ten equations were checked by applying the regression analysis. Because of the complex form of "x" and "y" expressions and their multicomponent composition, raw data were complemented with the mean values for the time period when the gap existed, in such a way as to keep the size of the sets identical before starting the statistical analysis. This was done to prevent the elimination of a great number of data, as the result of missing data for one of the elements. Moreover, all data coming from the time periods in which the average temperature for the analyzed level was equal or lower than 4^oC were excluded, because at this temperature the rate of several of the described processes becomes equal to zero according to Dutt et al. (1972) and Gilmour et al. (1977). Therefore, the analyzed experimental period was reduced both in 1979 and 1980 by eliminating December as inconclusive. Independently from this, the influence of the temperature was taken into account by adjusting the rate constant (K) for changes in the temperature, using the generally applied expression:

$$k_{T_1} = k_{T_2} \cdot Q^{T_1 - T_2} \qquad (23)$$

where:

- k_{T_1} - rate constant corrected for temperature changes in the soil system;
- k_{T_2} - rate constant measured under optimum temperature;
- T_1 - temperature of the system to which rate constant needs to be corrected, ^oC;
- T_2 - temperature at which rate constant was measured, ^oC; and
- Q - 1.07, temperature correction coefficient.

Expression 23, as it was shown by Walter et al. (1974), can be applied for the mineralization only for the temperature range of 0^o to 35^oC.

The influence of pH was taken into consideration only for the process of nitrification, which is sensible for the range of pH changes, that were observed during BLWRS operation. From the data reported by Dancer et al. (1973), Frederick and Broadbent (1966), and Hagin and Amberger (1974), the following relationship was obtained to estimate relative rate of nitrification: $F_{pH} = 0.307$ pH - 1.269 for $4.5 \leq pH \leq 7.0$; $F_{pH} = 1.00$ for $7.0 \leq pH \leq 7.4$; and $F_{pH} = 5.367 - 0.599$ pH for $7.4 \leq pH \leq 9.0$.

The influence of soil moisture on the rate of ammonification, nitrification, denitrification, and decarboxylation was considered in the calculations of the process rate constant, with the assumption that the rate constant is not clean and contains element F_m, which expresses the relative rate (ranging from 0.0 to 1.00) of these processes. The F_m value for the processes of ammonification, nitrification, and decarboxylation was assumed to be constant and equal to 0.66 of their optimum rate. Daily moisture measurements were impossible because they would have produced process disturbances. Therefore, the number of soil samplings was limited to several times during the experiment. That is why the calculations of the relative rate of the processes "F_m" was based on the average moisture characteristic for the soil in the aerobic BLWRS zone during the time of experiment. This moisture content was equal to 7.70%, while the moisture corresponding to 60% of the soil saturation, reported by Kononova (1961) and Greaves and Carter (1920) as the optimum in the processes of ammonification, nitrification, and decarboxylation, will be 11.69% for the BLWRS soil.

The determination of F_m value for the process of denitrification appeared to be impossible because of the lack of data characterizing this process in the aerobic zone conditions with anaerobiosis appearing only locally. The empirical curve of the dependence of F_m, for denitrification, on relative soil-water content (water content/saturated water content) given by Rolston et al. (1980) breaks off on the level of relative moisture equal to 0.79 of the soil saturation.

Statistical analysis carried for all mentioned parameters and equations showed that Equation 18 was the only one that the correlation coefficient exceeded 0.7. The rest of the equations were characterized by the correlation coefficients contained in Table 26.

High correlation coefficients for Equation 18 were observed in the case of all analyzed parameters, all combinations of BLWRS sections, and each investigated period of experiment. Moreover, in each of these cases correlations appeared to be statistically significant because T_{exp} was always higher than T_t read from the tables for the given signficance level and for the described degrees of freedom.

The results of the statistical analysis carried for the simple regression y = b + ax where:

$$y = \lg \frac{(C_o - C_m) \cdot Q}{m \cdot F} \qquad (24)$$

$$x = \lg \frac{C_o \cdot Q}{m \cdot F} \qquad (25)$$

are contained in Table 27.

The investigations of the significance of the differences between the regression coefficients of the equations (derived on the basis of Equation 18) carried out based on the "T" test, showed the lack of significant differences between the sets of data characteristics for BLWRS-12 and BLWRS-34, both in 1979 and in 1980, in the case of such indicators of pollution as COD, C_{org}, TKN, and N_{org}. Therefore, transformations of these pollutants, in vertical profile of BLWRS aerobic zone during the whole experimental period, can be described by a single equation, which is common for all the sets of data concerning the investigated indicators of pollution. Transformations of C compounds can be described by the following equations:

$$\frac{(COD^o - COD^m) \cdot Q}{m \cdot F} = 0.8904 \left(\frac{COD^o \cdot Q}{m \cdot F}\right)^{0.9733} \left[\frac{mg}{dm^3 \cdot day}\right] \qquad (26)$$

TABLE 26. THE RANGE OF CORRELATION COEFFICIENTS FOR EQUATIONS 13 - 17 AND 19 - 22

Equation Number	Parameter	r From	r To
13	COD	-0.22	-0.36
	C_{org}	-0.06	-0.18
	TKN	-0.25	-0.51
	N_{org}	-0.10	-0.19
	TN	-0.37	-0.44
14	COD	-0.27	-0.57
	C_{org}	-0.19	-0.41
	TKN	-0.31	-0.71
	N_{org}	-0.21	-0.50
	TN	-0.37	-0.55
15	COD	-0.30	-0.51
	C_{org}	-0.12	-0.33
	TKN	-0.27	-0.65
	N_{org}	-0.23	-0.42
	TN	-0.36	-0.52
16	COD	0.15	0.44
	C_{org}	0.21	0.38
	TKN	0.23	0.66
	N_{org}	0.04	0.39
	TN	0.33	0.56
17	COD	-0.01	-0.21
	C_{org}	-0.03	-0.21
	TKN	0.01	-0.32
	N_{org}	0.00	-0.13
	TN	0.06	-0.32
19	N_{org}	0.01	-0.77
20	TKN	0.06	0.40
21	TKN	-0.30	-0.72
22	TN	-0.26	-0.56

TABLE 27. PARAMETERS OF THE REGRESSION EQUATION y = b + ax, CHARACTERIZING EXPRESSION 18 AT THE ASSUMED LEVEL OF THE CORRELATION PROBABILITY 1 - α = 99%

Nutrient	Combination of BLWRS Sections	Year	Degrees of Freedom N-2	Correlation Coefficient r	T_{exp}	T_t	Regression Coefficient a	Free Term b	Standard Error of the Regression Coefficient s (a)	Sum of the Error Squares ESS = $(1-r^2)\Sigma(y-\bar{y})^2$
1	2	3	4	5	6	7	8	9	10	11
TKN	12	79	51	0.89	14.02	2.680	0.9157	-0.1252	0.0653	0.8030
	34	79	44	0.98	30.51	2.695	0.9465	-0.0607	0.3102	11.1224
	12+34	79	99	0.94	26.39	2.632	0.9087	-0.0747	0.3443	19.4575
	12	80	73	0.94	23.65	2.651	0.9101	-0.0439	0.3848	7.0981
	34	80	73	0.81	11.89	2.651	0.8087	-0.0032	0.0680	7.0094
	12+34	80	148	0.88	22.05	2.576	0.8588	-0.0237	0.0390	14.1167
	12	79+80	128	0.92	26.92	2.576	0.8665	-0.0350	0.0322	17.6173
	34	79+80	119	0.92	24.99	2.617	0.9071	-0.0587	0.0363	19.1331
	12+34	79+80	247	0.92	36.83	2.576	0.8850	-0.0463	0.0240	36.9865
N_{org}	12	79	47	0.93	18.01	2.689	0.9609	-0.0631	0.0533	11.9034
	34	79	40	0.96	21.13	2.704	0.9849	-0.1225	0.0466	15.8590
	12+34	79	89	0.95	29.01	2.639	0.9837	-0.1005	0.0339	29.8199
	12	80	55	0.90	15.54	2.671	0.9999	-0.1094	0.0643	13.5807
	34	80	54	0.87	13.05	2.673	0.9820	-0.1579	0.0752	15.0323
	12+34	80	111	0.88	20.00	2.623	0.9897	-0.1330	0.0495	28.6623
	12	79+80	104	0.93	26.63	2.629	0.9903	-0.0975	0.0372	31.6138
	34	79+80	96	0.92	22.93	2.634	0.9896	-0.1456	0.0432	32.0792
	12+34	79+80	202	0.93	35.24	2.576	0.9953	-0.1234	0.0282	65.1542
TN	12	79	42	0.83	9.58	2.700	0.7781	-0.0259	0.0812	4.0293
	34	79	38	0.96	22.58	2.741	0.9971	-0.1785	0.0442	11.5111
	12+34	79	82	0.92	21.81	2.644	0.9148	-0.1407	0.0419	15.7592
	12	80	37	0.81	8.42	2.718	0.8809	-0.2094	0.1046	4.3243
	34	80	12	0.92	8.08	3.055	1.0192	-0.2176	0.1261	1.6430
	12+34	80	51	0.83	10.67	2.680	0.9133	-0.2087	0.0856	6.0430
	12	79+80	81	0.84	14.09	2.645	0.8694	-0.1597	0.0617	10.0209
	34	79+80	52	0.96	24.47	2.678	1.0008	-0.1873	0.0409	13.2497
	12+34	79+80	135	0.90	24.28	2.576	0.9306	-0.1821	0.0383	23.2719

(Continued)

TABLE 27 Continued

Nutrient	Combination of BLWRS Sections	Year	Degrees of Freedom N-2	Correlation Coefficient r	T_{exp}	T_t	Regression Coefficient a	Free Term b	Standard Error of the Regression Coefficient s (a)	Sum of the Error Squares ESS = $(1-4^2)\Sigma(y-\bar{y})^2$
1	2	3	4	5	6	7	8	9	10	11
COD	12	79	52	0.98	33.48	2.678	0.9969	-0.0923	0.0298	9.4868
	34	79	45	0.99	42.89	2.693	0.9924	-0.0637	0.0231	18.0869
	12+34	79	99	0.98	56.36	2.632	0.9900	-0.0698	0.0176	28.5401
	12	80	73	0.97	33.31	2.651	0.8903	0.0441	0.0267	5.5908
	34	80	75	0.83	12.96	2.651	0.9484	-0.0483	0.0732	12.7579
	12+34	80	148	0.87	21.89	2.576	0.9194	0.0235	0.0420	18.3537
	12	79+80	127	0.98	56.78	2.576	0.9484	0.0056	0.0167	21.3706
	34	79+80	120	0.93	27.88	2.617	0.9885	0.0897	0.0355	32.8457
	12+34	79+80	249	0.95	48.36	2.576	0.9733	-0.0504	0.0201	54.8135
C_{org}	12	79	41	0.80	8.51	2.702	0.9923	-0.1908	0.1166	11.2706
	34	79	45	0.94	18.53	2.693	1.0030	-0.1640	0.0541	18.9277
	12+34	79	88	0.89	18.74	2.640	0.9899	-0.1678	0.0528	31.4581
	12	80	65	0.89	16.10	2.656	1.0010	-0.1215	0.0622	12.0765
	34	80	70	0.94	22.26	2.653	1.0470	-0.1784	0.0470	14.2114
	12+34	80	137	0.92	26.94	2.576	1.0247	-0.1501	0.0380	26.4213
	12	79+80	108	0.86	17.61	2.625	0.9590	-0.1056	0.0545	25.6879
	34	79+80	117	0.94	29.22	2.620	1.0198	-0.1626	0.0349	33.1391
	12+34	79+80	227	0.90	32.05	2.576	0.9932	-0.1390	0.0310	58.9989

$$\frac{(C_{org}^{o} - C_{org}^{m}) \cdot Q}{m \cdot F} = 0.7261 \left(\frac{C_{org}^{o} \cdot Q}{m \cdot F}\right)^{0.9932} \left[\frac{mg}{dm^3 \cdot day}\right] \qquad (27)$$

Process of ammonification is characterized by the expression:

$$\frac{(N_{org}^{o} - N_{org}^{m}) \cdot Q}{m \cdot F} = 0.7527 \left(\frac{N_{org}^{o} \cdot Q}{m \cdot F}\right)^{0.9953} \left[\frac{mg}{dm^3 \cdot day}\right] \qquad (28)$$

Process of nitrification determined by reduction of TKN can be expressed by the following equation:

$$\frac{(TKN^{o} - TKN^{m}) \cdot Q}{m \cdot F} = 0.8989 \left(\frac{TKN^{o} \cdot Q}{m \cdot F}\right)^{0.8850} \left[\frac{mg}{dm^3 \cdot day}\right] \qquad (29)$$

In the case of TN in 1979 the significant difference between the set of data characteristics for BLWRS-12 and BLWRS-34 was noted; however in 1980, these differences were insignificant. The comparison of 1979 and 1980 data sets characteristics for BLWRS-12 and the same analyses carried out for BLWRS-34 indicated that for TN differences between years are statistically insignificant. It was also shown, still based on the T test, that differences between data set characteristics for BLWRS-12 for the whole experimental period and the corresponding BLWRS-34 data set are insignificant. This fact enables the description of the TN transformations in the vertical profile of BLWRS aerobic zone, during the whole experimental period, with the help of the following equation, characteristics for the process of denitrification in the aerobic zone of the vertical BLWRS profile:

$$\frac{(TN^{o} - TN^{m}) \cdot Q}{F \cdot m} = 0.6575 \cdot \left(\frac{TN^{o} \cdot Q}{F \cdot m}\right)^{0.9306} \left[\frac{mg}{dm^3 \cdot day}\right] \qquad (30)$$

For the practical use of the above described equations, the following forms of these expressions are proposed:

$$\frac{C_m}{C_o} = 1 - a.\left(\frac{F \,.\, m}{C_o \,.\, Q}\right)^{1-b} \quad (31)$$

$$\frac{C_o - C_m}{C_o} = a.\left(\frac{F \,.\, m}{C_o \,.\, Q}\right)^{1-b} \quad (32)$$

$$\frac{Q}{F} = \frac{m}{C_o} \sqrt[1-b]{\frac{a}{\eta}} \quad (33)$$

where: $\eta = \frac{C_o - C_m}{C_o}$

OXYGEN CONDITIONS IN BLWRS

Oxygen conditions in the experimental bed were described by the oxygen balance. The oxygen demand for the biochemical transformations taking place in 10 cm layers of BLWRS was estimated based on the following relationship:

$$O_2 = a' \,.\, \Delta\, COD + c' \,.\, \Delta\, TKN + c'' \,.\, \Delta\, TKN - d' \,.\, \Delta\, TN - d'' \,.\, \Delta\, TN \quad (34)$$

where: $a' = (1 - a \,.\, 1.42) = 1.0$
$c' = k \,.\, 4.60$
$c'' = 1 \,.\, 0.67 \,.\, 4.60$
$d' = k \,.\, 2.86$
$d'' = 1 \,.\, 0.67 \,.\, 2.86$

Values of Δ COD, Δ TKN, and Δ TN for the selected layers were estimated from the equations given in the preceding section. Coefficient a' = 1.0 is the consequence of Δ COD of unfiltered sample and results also from the calculations presented in the kinetics section. Values of 4.60 $\left(\frac{g.O_2}{g.TKN}\right)$ and 2.86 $\left(\frac{g.O_2}{g.TN}\right)$ are conversion factors generally applied in nitrification and denitrification k and l values equal, respectively, 0.95 and 0.05, illustrate the average participation of $N\text{-}NO_3$ and $N\text{-}NO_2$ in the above mentioned processes. The average ratio of $N\text{-}NO_3 : N\text{-}NO_2$ in BLWRS, calculated on the values of both of these N forms in the wastes sampled at depths of 0, 30, 80, 140, 160, and 180 cm excluding the sampling points below the energy source, equals 19.5. Value 1.54 is the average from the value of 1.66 i.e. the Total Oxygen Demand (TOD) of the raw wastes sludge calculated from Table 28 and the generally applied value of 1.42 i.e. TOD for the activated sludge. The sludge in BLWRS consists approximately in 50% of the sludge carried with the wastes and in 50% from the sludge synthesized from the wastes; therefore, it seems to be right to accept the average value of $\frac{\text{TOD}}{\text{sludge VSS}}$ equal to 1.54 as the one which illustrates the unit TOD of the BLWRS sludge.

Values of the oxygen demand for the biochemical processes occurring in the selected 10 cm BLWRS layers are given in Table 29. Changes of the oxygen demand (for the biochemical processes in BLWRS) with the depth of the bed are illustrated by Figure 11. Average daily oxygen demand for the biochemical processes in BLWRS, calculated on the basis of the values from the whole experimental period, equals 76.6 kg $O_2 \cdot day^{-1}$.

The amount of oxygen, which is transferred into the BLWRS, during the day, with the assumption of molecular diffusion of one direction, was calculated according to the equation describing the stream of diffusing gas (G_A), given by Hobler (1962):

$$G_A = N_A \cdot F' \text{ (kg A/day)} = 65.5 \text{ (kg } O_2 \cdot day^{-1}) \qquad (35)$$

where: F' - surface of the layer's cross section $= 0.375 \cdot 0.345 \cdot 1500 = 194.1 \ m^2$

0.375 - pore space of BLWRS soil

0.345 - percentage of pore space occupied by water at the average (two-years) moisture content in aerobic BLWRS zone equal 7.7%

1500 - BLWRS surface, m^2

TABLE 28. CHEMICAL COMPOSITION OF THE SLUDGE CONTAINED IN THE WASTES APPLIED TO BLWRS

Parameter	BLWRS-12								Mean Value
Percentage Composition									
N	6.95	3.68	6.67	7.99	7.47	8.70	7.02	6.31	6.85
C	41.09	20.12	38.89	36.31	36.17	39.51	42.15	36.39	36.33
H	6.47	4.42	6.27	6.20	6.14	6.18	6.36	5.49	5.94
P	12.49	4.78	18.17	23.50	24.23	26.61	23.77	21.51	19.38
Elemental Composition									
N	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C	6.90	6.38	6.80	5.30	5.65	5.30	7.01	6.73	6.26
H	13.03	16.81	13.16	10.86	11.51	9.95	12.68	12.18	12.52
O	1.57	1.14	2.38	2.57	2.84	2.68	2.96	2.98	2.39
Sludge VSS ($\frac{mg}{l}$)	113.0	136.0	108.0	500.0	1,064.0	688.0	348.9	69.7	378.5
Sludge TOD ($\frac{mg\ O_2}{l}$)	228.5	323.5	191.8	738.4	1,499.0	961.7	561.2	108.7	576.6
$\frac{TOD}{VSS}$ ($\frac{g\ O_2}{g\ VSS}$)	2.02	2.38	1.78	1.48	1.41	1.40	1.61	1.56	1.71

(Continued)

TABLE 28 Continued

Parameter								Mean Value
	BLWRS-34							
Percentage Composition								
N	6.83	6.47	8.06	8.05	6.90	6.67	7.65	7.23
C	40.22	38.59	33.64	37.37	43.86	36.58	40.88	38.73
H	6.38	6.34	5.36	6.01	6.72	6.00	6.02	6.12
O	16.57	21.13	25.94	26.14	11.52	23.65	26.45	21.63
Elemental Composition								
N	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C	6.87	6.96	4.87	5.42	7.42	6.40	6.23	6.31
H	13.08	13.72	9.31	10.45	13.63	12.59	11.02	11.97
O	2.12	2.86	2.82	2.84	1.46	3.10	3.03	2.60
Sludge VSS $(\frac{mg}{l})$	196.0	95.0	940.0	750.9	708.0	233.3	259.2	454.6
Sludge TOD $(\frac{mg\ O_2}{l})$	364.2	134.8	1,194.4	1,044.0	1,512.4	395.0	376.6	717.3
$\frac{TOD}{VSS}$ $(\frac{g\ O_2}{g\ VSS})$	1.86	1.42	1.27	1.39	2.14	1.69	1.45	1.60

TABLE 29. OXYGEN DEMAND FOR BIOCHEMICAL PROCESSES OCCURRING IN THE SELECTED 10 CM BLWRS LAYERS - AVERAGE VALUES FROM THE WHOLE EXPERIMENTAL PERIOD

Thickness (cm)	Layer (cm)	Δ COD $\frac{mg\ O_2}{dm^3 \text{ of soil.day}}$	Δ TKN $\frac{mg\ N}{dm^3 \text{ of soil.day}}$	Δ TN $\frac{mg\ N}{dm^3 \text{ of soil.day}}$	Oxygen Consumed or Produced in the Processes of ($mg\ O_2/dm^3$ of BLWRS soil . day) Carboxylation	Nitrification $N\text{-}NO_3$	Nitrification $N\text{-}NO_2$	Denitrification $NO_3\text{-}N_2$	Denitrification $NO_2\text{-}N_2$	ΣO_2
5	0- 10	306.10	34.90	20.60	306.1	152.5	5.4	56.0	2.0	406.0
15	10- 20	33.20	5.16	4.44	33.2	22.5	0.8	12.1	0.4	44.0
25	20- 30	13.70	2.35	2.16	13.7	10.3	0.4	5.9	0.2	18.3
35	30- 40	7.80	1.45	1.41	7.8	6.3	0.2	3.8	0.1	10.4
55	50- 60	3.70	0.73	0.79	3.7	3.2	0.1	2.1	0.1	4.8
75	70- 80	2.20	0.47	0.54	2.2	2.1	0.1	1.5	0.1	2.8
95	90-100	1.50	0.33	0.40	1.5	1.4	0.1	1.1	0.0	1.9
115	110-120	1.10	0.25	0.32	1.1	1.1	0.0	0.9	0.0	1.3
155	150-160	0.70	0.16	0.22	0.7	0.7	0.0	0.6	0.0	0.8

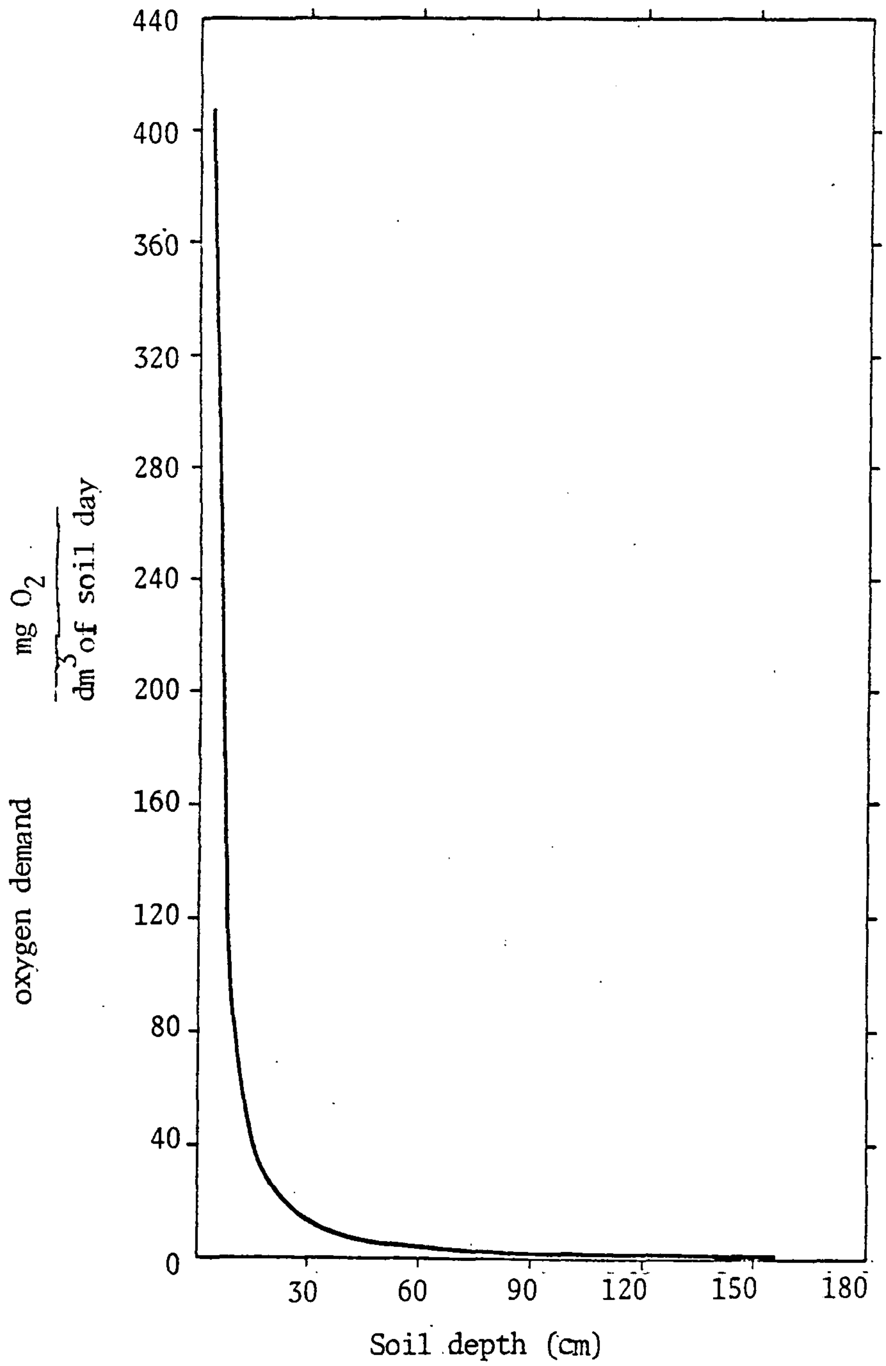

Figure 11. Oxygen demand for the biochemical processes as a function of BLWRS depth.

N_A - density of the stream of the A component's mass, $\frac{kg}{m^2 \cdot day}$

$$N_A = \frac{\delta A . \Delta y}{S . y_{in}} \tag{36}$$

δ_A - dynamic gas diffusion coefficient at $10^{o}C$ (average daily temperature from the whole experimental period) in the oxygen - air system = 2.9109×10^{-5} $\frac{kmol}{m.hour}$

S - way of diffusion = 0.5 height of the BLWRS aerobic zone = 0.6 m

$\frac{\Delta y}{y_{in}}$ - driving modulus of diffusion, quotient of the difference of the mass oxygen ratios in atmospheric air and BLWRS air and the arithmetic mean value of the mass ratios of the rest of the air components = 9.06×10^{-2}

The comparison of the amount of oxygen consumed in the biochemical processes in BLWRS (76.6 kg O_2/day) with the amount of oxygen which theoretically should be transferred into BLWRS by molecular diffusion (65.5 $\frac{kg\ O_2}{day}$) doesn't allow us to exclude the possibility of an oxygen deficit in BLWRS with such an assumed system of O_2 transfer.

However, it seems more probably that oxygen was transferred into BLWRS by the gas exchange phenomenon. In this case the frequency of an air exchange (z) was calculated from the following expression:

$$z = \frac{V_B}{V_F} = \frac{TOD_B \cdot V_0^{10}}{M_o \cdot A \cdot F' \cdot h_A} = \frac{265.8}{232.9} = 1.14 \ (day^{-1}) \tag{37}$$

where: V_B - air volume equivalent of the oxygen volume used for the biochemical processes in BLWRS, m^3/day

V_F - air volume in free space of BLWRS, m^3

TOD_B - average daily oxygen demand for the biochemical transformations in BLWRS = 76.6 kg O_2/day

V_0^{10} - oxygen molecular volume, at p = 1 Atm and t = $10^{o}C$ (average daily temperature from the experimental period), equals to 23.24 m^3/kmol

M_o - oxygen molecular mass = 32 $\frac{kg}{kmol}$

A - volume fraction of oxygen in air = 0.2903

F' - free pore space in BLWRS = 149.1 m^2

h_A - depth of aerobic zone in BLWRS = 1.2 m

and equals 1.14 day^{-1}, while air velocity in the interface layer amounts to:

$$S_a = \frac{2\ V_B}{F'} = 2.74\ .\ 10^{-5}\ \text{(m/sec)} \qquad (38)$$

INFLUENCE OF LOW TEMPERATURE ON PROCESSES OCCURRING IN BLWRS

The influence of the decreased temperature on the processes occurring in BLWRS was investigated by comparing the efficiency of the removal of impurities in the periods before and after the cooling down.

August, September, and October was assumed as the warm period in 1979 while July, September, and October was treated as the warm period in 1980 (August 1980 was excluded because of the extremely low loadings of impurities introduced on BLWRS during this month). November was assumed to constitute the cold period, as in this month the lowest average daily temperature was noted; December was excluded as not characteristic because of a considerable decrease of BLWRS loadings taking place in this month. The effect of removal of impurities in BLWRS before and after the temperature decrease is presented in Table 30.

Table 30 shows the distinct decrease of the efficiency of the purification process together with the decrease of temperature in the first year of the experiment and in the case of all investigated parameters, however in the second year of BLWRS work, the temperature decrease has the negative influence only on the rate of TN removal. These observations are confirmed by the increase of COD and TKN loadings, drained from BLWRS during the cold period, which was observed in 1979 (Figure A-11, A-13, A-15, A-17, A-19, A-21, A-23, and A-25). By looking at the figures showing the cumulative loads of impurities in BLWRS effluents in 1979, it can be seen that the first temperature drops at the turn of October and November cause the raising of the curve's course, while the change of the slope didn't result from the increase of the loadings of impurities applied to BLWRS

TABLE 30. EFFECT OF REMOVAL OF IMPURITIES IN BLWRS BEFORE AND AFTER THE COOLNESS (VALUES EXPRESSED IN %)

		1979					1980				
Parameter	Period	Average Daily Temperature	BLWRS 1	BLWRS 2	BLWRS 3	BLWRS 4	Average Daily Temperature	BLWRS 1	BLWRS 2	BLWRS 3	BLWRS 4
TN	Cold	3.4°C	82.7	84.6	89.4	84.4	3.9°C	64.7	69.3	55.8	75.0
	Warm	13.4°C	90.0	90.0	90.4	90.8	12.7°C	71.0	73.4	70.9	79.7
TKN	Cold	3.4°C	87.6	79.5	94.4	96.2	3.9°C	91.9	84.6	67.3	92.7
	Warm	13.4°C	96.0	94.5	95.8	96.7	12.7°C	84.3	71.6	75.9	86.5
COD	Cold	3.4°C	96.8	93.9	98.2	98.6	3.9°C	97.5	95.8	94.3	97.4
	Warm	13.4°C	98.7	98.0	98.4	99.0	12.7°C	94.5	89.4	91.7	95.1
TP	Cold	3.4°C	99.5	98.5	99.7	99.7	3.9°C	97.1	96.1	95.2	98.7
	Warm	13.4°C	99.9	99.8	99.7	99.9	12.7°C	96.1	95.7	96.6	96.6

(Figure A-1, A-2, A-5, and A-7). In 1980 the temperature decrease influenced only the efficiency of TN removal. In the case of TKN, COD, and TP the decrease in the purification efficiency wasn't observed. Diagrams of the cumulative loads of TKN and COD drained from BLWRS in 1980 confirmed those observations (Figure A-12, A-14, A-16, A-18, A-20, A-22, A-24, and A-26). The slope of the curve, illustrating the relationship between the cumulative TKN and COD loads in the effluents and time, doesn't change in November; that indicates (with the unchanged BLWRS loadings which were observed in this period - Figure A-2, A-4, A-6, and A-8) that the efficiency of the purification process was maintained, on the average, at the same level as in the period of time before the temperature decrease.

If the reduction of denitrification rate in BLWRS in 1980 was caused only by the temperature decrease and the rest of the factors influencing this process were not changed, it should be followed by the increase of the oxidized forms of N, that, indeed, was observed.

The average concentration of the oxidized forms of N in the effluents from the section with energy insert and from the section without the additional energy source were as follows: in the warm period, BLWRS-14 - 128.9 mg/l and BLWRS-23 - 57.3 mg/l; in the cold period, BLWRS-14 - 242.9 mg/l and BLWRS-23 - 134.0 mg/l.

The above mentioned observations indicate high sensitivity of the BLWRS microflora to the change of temperature during the initial period of BLWRS work. However, after an adaptation period, this microflora seems to be considerably more resistant to the temperature reduction, with the exception of microorganisms responsible for denitrification. This last observation is consistent with the conclusions from the investigations on the influence of temperature on the process of denitrification, which were conducted by Focht (1974) and Baily and Beauchamp (1973).

They found, that in the process of denitrification (with optimum temperature equal to 65^oC - 75^oC) the effect of temperature upon the process rate adheres to Arrenhius kinetics except for temperatures below

20^oC. The rate is most drasically affected at lower temperatures, with reduction of nitrate being more affected than reduction of nitrite.

METALS IN WASTES

Animal fodder contains besides such basic components as C - 40.78%, P - 7.9%, N -2.35%, several metals, i.e. K - 0.55%, Na - 0.27%, Ca - 0.28%, Mg - 0.1%, Fe - 0.027%, Zn - 0.005%, Cu - 0.0009% as well as Cd - 0.00008%.

To estimate displacement of metals in BLWRS the analytical control of all samples taken from both systems was carried out. However precise, taking into account all aspects of phenomena, the analysis of the behavior of the investigated metals in the soil profile of BLWRS appeared to be practically impossible. The chemical reactions which may occur with components of the wastes and soil can be grouped conveniently, into ion exchange, adsorption and precipitation, and complexation. The mechanisms and rates of most, if not all, of these reactions are dependent upon the type and amounts of clay, hydrousoxides of metals, mainly Al, Mn, Fe, and organic matter, as well as more dynamic properties including solute composition and concentration, exchangeable cations, pH and oxidation - reduction status. The latter reactions are often profoundly affected by the physical and biological properties of soils. Therefore, analysis of the processes occurring between the BLWRS soil and metals contained in the wastes applied to the BLWRS seems to be so complicated and wide that it is beyond the frame of this work. The result of the interpretation was limited only to the presentation of the average annual concentrations of metals in the wastes taken from different levels of BLWRS as well as in the effluents and influents. These data are contained in Tables 31 - 34. Values presented in these tables were based on the series that average numerical force was equal for 1979 - 5, and for 1980 - 15. The balance of the metal loadings shows that during the investigated period of time considerable amounts of K, Na, Zn, Cu, Fe, Al, and Cd were removed by both systems. Calcium and magnesium were removed from wastes only in 1979. The analysis of metal accumulation in vertical profile of BLWRS indicates that most of the metals were removed in the top 30 cm of BLWRS-12 and BLWRS-34. This observation was confirmed by soil analysis.

TABLE 31. AVERAGE ANNUAL CONCENTRATIONS OF METALS IN WASTES, TAKEN AT SEVERAL DEPTHS IN BLWRS-12, SECTION 1 (VALUES IN mg/1)

Depth (cm)	Na	K	Ca	Mg	Zn	Cu	Fe	Al	Cd
					1979				
0	458.0	629.6	925.8	207.4	11.42	1.24	34.0	405.5	0.026
30	291.1	651.3	333.9	60.6	1.04	0.45	8.6	141.7	0.007
80	310.3	355.9	380.8	57.4	1.06	0.52	8.6	105.0	0.003
140	270.8	301.6	354.0	64.0	0.71	0.35	20.6	93.6	0.011
160	274.0	255.9	446.9	144.9	0.62	0.36	19.4	91.2	0.005
180	263.7	204.0	423.9	72.3	0.39	0.32	9.7	101.5	0.003
					1980				
0	87.0	334.1	172.0	49.6	1.52	0.30	6.3	6.9	-
30	88.8	216.8	255.5	71.8	1.66	0.20	5.5	6.3	-
80	78.0	253.4	383.4	54.4	0.56	0.27	3.8	12.1	-
140	82.3	222.3	433.2	55.4	0.58	0.40	6.5	7.4	-
160	88.1	204.4	432.3	64.3	0.56	0.26	6.1	9.1	-
180	68.0	207.5	351.7	48.6	0.59	0.30	6.0	5.6	-
					1981				
80	39.5	285.5	225.0	55.5	0.20	0.10	3.0	1.7	-
160	61.5	237.0	250.0	48.0	0.25	0.18	5.3	2.9	-
180	44.9	207.0	165.0	49.8	0.40	0.13	6.8	1.5	-

TABLE 32. AVERAGE ANNUAL CONCENTRATIONS OF METALS IN WASTES, TAKEN AT SEVERAL DEPTHS IN BLWRS-12, SECTION 2 (VALUES IN mg/1)

Depth (cm)	Na	K	Ca	Mg	Zn	Cu	Fe	Al	Cd
					1979				
0	458.0	629.6	925.8	207.4	11.42	1.24	34.0	405.5	0.026
30	291.1	651.3	333.9	60.6	1.04	0.45	8.6	141.7	0.007
80	310.3	355.9	380.8	57.4	1.06	0.52	8.6	105.0	0.003
140 a	284.3	293.8	383.5	75.6	0.61	0.34	22.8	91.2	0.006
140 b	165.2	212.1	272.5	43.5	1.13	0.42	57.3	83.2	0.011
160 a	267.6	243.7	410.2	72.4	0.86	0.39	35.3	90.5	0.007
160 b	219.2	181.5	401.8	60.6	0.65	0.34	61.2	101.2	0.005
180	260.7	181.0	340.0	61.1	0.89	0.26	24.5	89.9	0.004
					1980				
0	87.0	334.1	172.0	49.6	1.52	0.30	6.3	6.9	-
30	88.8	216.8	255.5	71.8	1.66	0.20	5.5	6.3	-
80	78.0	253.4	383.4	54.4	0.56	0.27	3.8	12.1	-
140 a	79.2	216.5	315.3	51.3	0.46	0.27	0.7	4.0	-
140 b	75.9	280.9	159.0	119.0	0.72	0.19	11.0	2.6	-
160 a	106.6	177.2	358.5	66.5	0.47	0.31	15.6	4.8	-
160 b	78.8	290.3	183.1	48.9	0.83	0.24	16.1	4.3	-
180	77.8	174.5	302.4	52.9	0.49	0.24	20.8	3.0	-
					1981				
0	39.5	285.5	225.0	55.5	0.20	0.10	3.0	1.7	-
140 a	49.3	247.8	122.5	67.3	0.13	0.14	28.5	1.4	-
140 b	64.0	299.0	.35.0	46.5	0.10	0.09	7.5	2.6	-
160 a	56.5	252.8	137.5	68.8	0.18	0.09	47.7	1.8	-
160 b	323.0	55.0	50.0	45.0	0.60	0.09	8.6	4.7	-
180	49.1	210.6	128.8	50.5	0.93	0.06	3.2	1.2	-

[a] before energy source
[b] after energy source

TABLE 33. AVERAGE ANNUAL CONCENTRATIONS OF METALS IN WASTES, TAKEN AT SEVERAL DEPTHS IN BLWRS-34, SECTION 3 (VALUES IN mg/1)

Depth (cm)	Na	K	Ca	Mg	Zn	Cu	Fe	Al	Cd
					1979				
0	263.5	744.0	623.0	111.4	22.72	3.40	69.4	37.2	0.046
30	267.4	626.2	186.5	62.2	1.00	0.47	6.5	6.3	0.001
80	517.8	540.5	271.3	80.0	3.91	0.72	11.2	11.7	0.018
140 a	275.2	104.7	357.1	72.4	0.39	0.35	10.4	7.6	0.004
140 b	247.8	330.9	308.0	74.1	1.46	0.58	17.5	11.1	0.007
160 a	248.8	94.1	394.2	70.5	1.15	0.71	11.4	6.1	0.003
160 b	224.1	149.4	284.4	63.3	0.85	0.27	17.6	4.6	0.002
180	261.5	210.6	306.4	74.7	0.66	0.32	16.1	5.4	0.004
					1980				
0	91.6	327.0	184.9	50.2	1.58	0.44	7.7	5.3	-
30	81.6	291.5	193.3	90.3	1.78	0.41	10.8	3.3	-
80	95.6	243.0	245.0	159.1	1.30	0.27	5.0	3.3	-
140 a	100.1	160.9	246.3	146.1	0.72	0.30	9.5	3.5	-
140 b	105.2	264.3	162.8	85.5	3.77	0.28	10.3	2.1	-
160 a	127.0	178.8	334.5	196.3	0.94	0.30	5.8	6.5	-
160 b	112.7	285.3	270.1	148.6	1.51	0.26	14.2	9.2	-
180	102.1	232.9	276.5	114.6	0.61	0.06	12.7	2.9	-
					1981				
140 a	62.0	202.5	77.5	177.5	0.25	0.13	28.7	1.6	-
140 b	36.25	171.5	95.0	58.8	0.28	0.16	22.9	2.1	-
160 a	63.5	180.0	165.0	218.5	0.50	0.13	13.9	0.0	-
180	59.3	207.0	308.75	71.6	0.79	0.19	7.8	4.0	-

[a] before energy source
[b] after energy source

TABLE 34. AVERAGE ANNUAL CONCENTRATIONS OF METALS IN WASTES, TAKEN AT SEVERAL DEPTHS IN BLWRS-34, SECTION 4 (VALUES IN mg/1)

Depth (cm)	Na	K	Ca	Mg	Zn	Cu	Fe	Al	Cd
					1979				
0	263.5	744.0	623.0	111.4	22.72	3.40	69.4	37.2	0.046
30	26.7	626.2	186.5	62.2	1.00	0.47	6.5	6.3	0.001
80	517.8	540.5	271.3	80.0	3.91	0.72	11.2	11.7	0.018
140	267.8	112.7	415.4	83.9	0.90	0.50	6.5	8.1	0.004
160	291.6	144.8	419.7	81.1	0.70	0.30	20.3	8.2	0.004
180	273.7	149.8	335.7	55.8	0.40	0.39	5.6	4.2	0.003
					1980				
0	91.6	327.0	184.9	50.2	1.58	0.44	7.7	5.3	-
30	81.6	291.5	193.3	90.3	1.78	0.41	10.8	3.3	-
80	95.6	243.0	245.0	159.1	1.30	0.27	5.0	3.3	-
140	104.0	187.4	257.7	165.6	0.40	0.24	7.3	4.8	-
160	127.6	179.1	274.7	165.1	0.52	0.29	5.7	4.7	-
180	91.1	208.4	231.7	105.8	0.57	0.28	6.1	5.0	-
					1981				
140	106.4	157.5	165.0	202.5	0.23	0.10	3.8	4.7	-
160	125.2	154.6	222.5	215.0	0.55	0.18	4.0	2.1	-
180	75.3	249.0	118.3	45.3	0.80	0.25	5.0	8.3	-

Moreover, it seems that in 1979 both BLWRS removed larger average daily loading of metals than in 1980 (Tables 35 - 38). This could be caused by the depletion of the accumulation capacity of the bed.

The analysis of metals in wastes showed that Ca and Mg were leached from both BLWRS, as was observed by Ritter and Eastburn (1978) in their work. The elution of Ca and Mg took place not earlier than in the second year of the experiment. In the effect of Mg elution from BLWRS, the influence of the blastfurnace slag cover was indicated, the quantity of Mg leached from BLWRS-34 in 1980 is more than two times higher than the Mg loading leached from BLWRS-12. The influence of the additional energy source on the change of the concentration of metals is indicated in the most obvious way in the case of Fe which is leached from the energy insert. In 1980 the Fe elution from BLWRS beds in Sections 2 and 3 was observed (Tables 36 and 37). Potassium is also leached from the energy insert, however in this case, the influence of the additional energy source is not so drastic. The statement concerning the elution of Fe and K from the energy insert was partially confirmed by the analysis of soil profiles of both BLWRS.

The concentration of Al in the wastes fed to BLWRS-12 in the period of investigations indicates that the operators of the purification plant applied aluminium sulphate for the coagulation of the wastes only in 1979. The low values of Cd concentration in the applied wastes as well as in the effluents show that under Polish conditions this metal is not a problem. Therefore, the analysis of Cd concentration in wastes was not continuated in 1980.

TABLE 35. SUMMARY OF AVERAGE DAILY LOADINGS OF METALS APPLIED AND DRAINED AND PERCENT REMOVAL OF METALS FOR BLWRS-12, SECTION 1

Metal	Amount Applied Average Daily Value (g)	Amount Removed Average Daily Value (g)	Removal (%)
		1979	
Na	960.0	462.7	51.8
K	1320.0	358.0	72.9
Ca	1941.0	744.0	61.7
Mg	434.8	126.9	70.8
Zn	23.90	0.68	97.2
Cu	2.60	0.56	78.5
Fe	71.30	16.99	76.2
Al	850.1	178.20	79.0
Cd	0.054	0.0053	90.2
		1980	
Na	127.6	105.0	17.7
K	490.0	320.5	34.6
Ca	252.3	543.4	-115.4
Mg	72.7	75.1	- 3.3
Zn	2.23	0.91	59.1
Cu	0.44	0.46	- 4.5
Fe	9.20	9.28	- 0.9
Al	10.2	8.57	15.9

TABLE 36. SUMMARY OF AVERAGE DAILY LOADINGS OF METALS APPLIED AND DRAINED AND PERCENT REMOVAL OF METALS FOR BLWRS-12, SECTION 2

Metal	Amount Applied Average Daily Value (g)	Amount Removed Average Daily Value (g)	Removal (%)
		1979	
Na	960.0	446.3	53.5
K	1320.0	309.9	76.5
Ca	1941.0	582.1	70.0
Mg	434.8	104.9	75.9
Zn	23.90	1.52	93.6
Cu	2.60	0.45	82.7
Fe	71.30	41.90	41.2
Al	850.1	153.90	81.9
Cd	0.054	0.0068	87.4
		1980	
Na	127.6	115.7	9.3
K	490.0	259.7	47.0
Ca	252.3	450.0	- 78.4
Mg	72.7	78.8	- 8.4
Zn	2.23	0.73	67.3
Cu	0.44	0.36	18.2
Fe	9.20	31.00	-237.0
Al	10.2	4.51	55.8

TABLE 37. SUMMARY OF AVERAGE DAILY LOADINGS OF METALS APPLIED AND DRAINED AND PERCENT REMOVAL OF METALS FOR BLWRS-34, SECTION 3

Metal	Amount Applied Average Daily Value (g)	Amount Removed Average Daily Value (g)	Removal (%)
		1979	
Na	553.4	400.1	27.7
K	1562.4	322.2	79.4
Ca	1308.3	468.8	64.2
Mg	233.9	114.3	51.1
Zn	47.70	1.01	97.9
Cu	7.14	0.49	93.1
Fe	145.70	24.60	83.1
Al	78.1	8.29	89.4
Cd	0.0097	0.0053	45.4
		1980	
Na	132.8	152.8	- 15.1
K	474.0	348.7	8.4
Ca	268.0	413.9	- 54.4
Mg	72.8	171.6	-135.7
Zn	2.29	0.91	60.3
Cu	0.64	0.09	85.9
Fe	11.20	19.00	- 69.6
Al	7.7	4.34	43.6

TABLE 38. SUMMARY OF AVERAGE DAILY LOADINGS OF METALS APPLIED AND DRAINED AND PERCENT REMOVAL OF METALS FOR BLWRS-34, SECTION 3

Metal	Amount Applied Average Daily Value (g)	Amount Removed Average Daily Value (g)	Removal (%)
		1979	
Na	553.4	352.7	36.3
K	1562.4	222.3	85.8
Ca	1308.3	498.2	61.9
Mg	233.9	82.8	64.6
Zn	47.7	0.59	98.8
Cu	7.14	0.58	91.9
Fe	145.70	8.31	94.3
Al	78.1	6.26	92.0
Cd	0.0097	0.0039	59.8
		1980	
Na	132.8	139.6	- 5.1
K	474.0	319.3	32.6
Ca	268.0	355.0	- 32.5
Mg	72.8	162.1	-122.7
Zn	2.29	0.87	62.0
Cu	0.64	0.43	32.8
Fe	11.20	9.34	16.6
Al	7.7	7.66	0.5

TRANSFORMATIONS OF THE CHEMICAL COMPOSITION OF BLWRS SOIL

The chemical analysis of the original BLWRS soil was presented in Table 5. The results of the subsequent analyses were made on samples collected December 5, 1979, and December 5, 1980, from eleven levels in each of the four sections of the BLWRS, all reported in Tables 39-50. It was observed that application of wastes on the BLWRS bed caused an increase in concentrations of the most of the investigated constituents, while the most evident increase was noted in the first 30 cm of the soil profile. The change in the concentrations of metals and nutrients in the soil profile of BLWRS in comparison to the values occurring in the original soil wasn't enough to change the order of the concentration values. The investigation on the soil profiles of both BLWRS indicated the lack of essential differences between the concentrations of nutrients and metals in 1979 and the concentrations of these constituents in 1980.

Organic substance accumulated in the top 0-5 cm is shown in the case of TKN, while the profiles of C_{org} and dry organic matter in the lower soil layers don't show any regularity, the concentration of TKN decrease along the soil profile reaching the original level at the depth of 40-45 cm. The influence of the additional energy source is quite clear in the case of C_{org} and dry organic matter. The concentration of both of these components in the soil samples collected from the places situated below the energy insert increases in comparison to the concentrations in the soil above the energy source.

The C_{inorg} profile, being disorderly, shows only the increase of the C_{inorg} concentration in soil, in comparison with the values occurring in the original BLWRS soil.

The analysis of the P soil profile was difficult because the concentration of this element in the original soil attained a very high level equal to 270 ppm. Therefore, this analysis indicates only the occurrence of the same magnitude of the P concentration along the whole soil profile that was conditioned by the initial P content in BLWRS soil. It is impossible to separate two special zones in any of the BLWRS beds, i.e. a zone of precipitation and a zone lying immediately below it, or a zone of P concentration in the waste samples from the inside of BLWRS and from the effluents and influents, presented in Subsections: "Characteristics of BLWRS Effluents" and "Transformations of Impurities - BLWRS Vertical Profile" indicates the occurrence of these layers.

The analysis of the metal profile shows the occurrence of several times higher concentrations of K, Na, Ca, Mg, Zn, Fe, and Al in the top 20-25 cm of BLWRS-34 when compared with the corresponding BLWRS-12 layer. This effect was caused by the layer of the blastfurnace slag with which BLWRS-34 was covered. Moreover, the profiles of metals indicate that most of metal impurities is removed in the top 30 cm. The elution of metals from the energy insert can be observed quite clearly in the case of K and Fe - the soil samples collected near the energy source, just as it is in the liquid phase, have the higher concentrations of these elements than the samples taken from the places situated above the energy insert.

The comparison of the proportion of the concentrations of constituents in the solution and soil made it possible to separate metals and nutrients, coefficients of distribution for the four investigated levels in the soil profile, indicating the relative stability. The coefficients for Ca, K, Mg, and C_{org} in BLWRS-12 and BLWRS-34 are presented in Tables 51 and 52. Examination of the values contained in these tables indicates the lack of the essential differences between coefficients of distribution for solution/soil for K, Ca, and Mg, in the same BLWRS, that would suggest the domination of the sorption phenomenon. The different conditions of sorption and desorption of metals from the soil complex prevailing in both BLWRS are illustrated only by the differences in the values of the coefficient of distribution observed for Ca; in BLWRS-12 the coefficient of distribution is on an average twice as high as in BLWRS-34. The coefficient of distribution solution/soil for C_{org} in the case of both BLWRS shows the same regularity. In the surface layer this coefficient is an order of the magnitude higher than the coefficients in the layers below the first 5 cm of the soil profiles of all four sections of the investigated BLWRS.

TABLE 39. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-12, DECEMBER 5, 1979, IN PPM - NUTRIENTS

Depth (cm)	C_{inorg}	C_{org}	Organic Solids	TKN	Total P
			Section 1		
0- 5	11,000	18,300	60,400	650	587
5- 10	12,100	14,300	54,800	190	527
10- 15	16,200	11,100	43,000	400	552
15- 20	-	15,100	59,000	180	482
20- 25	10,800	9,900	43,100	120	397
40- 45	9,900	9,500	39,000	100	312
60- 65	10,900	10,900	42,500	60	328
80- 85	9,200	10,300	41,500	30	392
100-105	5,400	12,400	50,200	100	387
120-125a	11,300	13,900	54,800	70	252
120-125b	11,300	13,900	54,800	70	-
140-145a	7,800	11,200	48,500	80	267
140-145b	7,800	11,200	48,500	80	-
			Section 2		
0- 5	7,200	12,800	45,900	380	362
5- 10	9,200	10,300	44,800	200	347
10- 15	10,400	11,900	47,800	180	312
15- 20	15,500	10,200	43,900	110	417
20- 25	11,100	11,000	46,300	150	307
40- 45	-	10,600	42,300	130	312
60- 65	12,200	11,900	49,000	20	342
80- 85	10,400	10,900	44,600	60	332
100-105	12,900	14,300	59,100	80	367
120-125a	10,600	11,500	45,900	40	322
120-125b	21,900	14,400	56,600	140	542
140-145a	-	10,500	43,800	30	262
140-145b	12,800	17,500	68,600	130	352

[a] before energy source
[b] after energy source

TABLE 40. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-34, DECEMBER 5, 1979, IN PPM - NUTRIENTS

Depth (cm)	C_{inorg}	C_{org}	Organic Solids	TKN	Total P
			Section 3		
0- 5	9,900	12,100	57,000	630	347
5- 10	12,800	14,300	68,400	440	362
10- 15	12,500	13,400	60,400	450	412
15- 20	17,000	12,200	50,600	260	422
20- 25	15,100	13,700	55,600	270	402
40- 45	11,000	11,300	45,100	190	312
60- 65	15,500	9,000	36,800	50	287
80- 85	7,400	11,000	43,600	50	342
100-105	12,200	8,500	33,100	50	297
120-125a	12,200	10,500	40,700	50	402
120-125b	11,600	10,000	41,200	80	297
140-145a	11,100	13,300	54,200	40	247
140-145b	9,400	8,800	40,300	40	302
			Section 4		
0- 5	10,100	21,200	71,600	2900	1297
5- 10	10,100	12,700	54,900	610	412
10- 15	11,400	13,700	59,200	500	347
15- 20	11,900	9,800	42,300	340	467
20- 25	14,000	12,400	52,200	110	287
40- 45	15,300	9,000	38,000	270	402
60- 65	9,100	8,300	33,400	40	372
80- 85	8,700	11,700	46,700	190	357
100-105	12,800	10,600	40,700	170	437
120-125a	11,600	9,800	39,500	50	297
120-125b	11,600	9,800	39,500	50	-
140-145a	11,300	9,200	36,800	70	252
140-145b	11,300	9,200	36,800	70	-

[a]before energy source
[b]after energy source

TABLE 41. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-12, DECEMBER 5, 1980, IN PPM - NUTRIENTS

Depth (cm)	C_{inorg}	C_{org}	Organic Solids	TKN	Total P
			Section 1		
0- 5	12,900	21,000	-	980	732
5- 10	13,200	14,800	55,300	440	542
10- 15	9,500	11,200	-	160	537
15- 20	9,000	10,700	43,000	80	557
20- 25	8,600	10,900	-	70	382
40- 45	12,100	12,200	25,200	60	482
60- 65	9,100	11,800	46,800	40	407
80- 85	9,400	10,700	43,200	60	487
100-105	12,400	11,200	-	40	317
120-125a	10,500	13,300	58,500	40	337
120-125b	10,500	13,300	58,500	40	-
140-145a	6,100	11,300	37,200	70	507
140-145b	6,100	11,300	37,200	70	-
			Section 2		
0- 5	7,300	10,200	42,900	450	372
5- 10	11,300	14,400	-	290	572
10- 15	9,700	9,200	-	250	527
15- 20	10,300	13,300	-	190	397
20- 25	7,700	10,500	-	100	412
40- 45	10,600	11,100	-	80	382
60- 65	9,500	11,600	58,000	30	327
80- 85	9,000	12,000	45,300	100	432
100-105	9,600	12,000	48,800	120	662
120-125a	9,000	11,400	-	50	407
120-125b	14,200	13,600	50,200	60	497
140-145a	8,000	9,800	-	50	262
140-145b	13,200	15,100	59,500	50	482

[a] before energy source
[b] after energy source

TABLE 42. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-34, DECEMBER 5, 1980, IN PPM - NUTRIENTS

Depth (cm)	C_{inorg}	C_{org}	Organic Solids	TKN	Total P
			Section 3		
0- 5	5,900	24,100	89,600	1610	1397
5- 10	10,400	12,100	55,100	480	602
10- 15	7,800	18,000	67,500	210	402
15- 20	10,400	14,700	-	110	397
20- 25	12,700	11,700	-	110	447
40- 45	15,100	14,000	-	80	432
60- 65	11,900	8,800	35,500	80	457
80- 85	7,500	9,500	-	110	-
100-105	6,500	9,600	38,200	100	457
120-125a	10,600	10,900	-	50	417
120-125b	9,500	13,100	-	50	372
140-145a	12,600	10,700	41,400	50	317
140-145b	11,400	13,200	51,800	100	362
			Section 4		
0- 5	8,300	20,100	-	1160	2227
5- 10	11,300	11,900	-	450	597
10- 15	8,000	14,000	-	320	622
15- 20	9,600	13,900	56,900	190	302
20- 25	8,900	9,900	39,000	240	297
40- 45	7,200	9,800	40,400	70	417
60- 65	10,100	12,400	-	60	377
80- 85	9,700	10,900	40,200	40	307
100-105	-	10,100	35,300	50	432
120-125a	7,400	9,500	-	60	382
120-125b	7,400	9,500	-	60	-
140-145a	8,300	9,800	-	40	372
140-145b	8,300	9,800	-	40	-

[a]before energy source
[b]after energy source

TABLE 43. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-12, SECTION 1, DECEMBER 5, 1979 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	1,390.0	21.9	32,920	3,562.5	65.00	0.0	4,762.5	3,200.0
5- 10	1,358.8	146.9	28,920	3,000.0	14.25	35.0	3,962.5	4,100.0
10- 15	1,296.3	165.6	34,920	2,750.0	19.75	17.5	3,812.5	2,425.0
15- 20	1,015.0	25.0	32,920	2,187.5	9.00	0.0	3,237.5	3,075.0
20- 25	1,015.0	0.0	21,420	1,687.5	9.00	17.5	2,737.5	1,400.0
40- 45	1,046.3	0.0	23,420	1,845.0	14.25	0.0	2,937.5	1,487.5
60- 65	6,296.3	62.5	17,170	1,687.5	212.50	0.0	1,912.5	2,750.0
80- 85	1,140.0	0.0	22,670	2,062.5	7.25	0.0	3,137.5	1,625.0
100-105	938.8	3.1	24,420	2,250.0	9.00	0.0	3,137.5	2,237.5
120-125	1,046.3	15.6	25,670	2,187.5	250.00	12.5	3,212.5	1,537.5
140-145	1,077.5	259.4	25,920	1,720.0	15.25	310.0	2,337.5	1,750.0

TABLE 44. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-12, SECTION 2, DECEMBER 5, 1979 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	1,108.8	3.1	21,420	1,687.5	14.75	0.0	3,412.5	975.0
5- 10	1,077.5	87.5	23,420	1,812.5	13.75	0.0	3,012.5	925.0
10- 15	1,140.0	9.4	25,670	2,345.0	10.75	32.5	2,937.5	2,775.0
15- 20	1,296.3	153.1	27,920	2,407.5	9.50	22.5	3,987.5	1,850.0
20- 25	1,265.0	40.6	31,670	2,625.0	9.00	2.5	4,637.5	2,325.0
40- 45	1,046.3	34.4	25,170	2,375.0	8.25	5.0	3,587.5	3,800.0
60- 65	952.5	0.0	25,170	1,970.0	7.75	0.0	3,287.5	1,750.0
80- 85	890.0	6.3	22,420	2,095.0	5.50	0.0	2,112.5	1,437.5
100-105	1,233.8	96.9	32,170	3,062.5	9.00	10.0	4,287.5	2,187.5
120-125a	952.5	271.9	31,420	2,157.5	6.50	0.0	2,962.5	2,537.5
120-125b	1,483.8	212.5	31,860	2,533.3	2.74	142.5	3,337.5	2,500.0
140-145a	858.8	53.1	27,170	2,125.0	8.50	5.0	2,687.5	1,250.0
140-145b	1,140.0	18.8	33,420	2,907.5	7.00	0.0	4,387.5	2,112.5

[a]before energy source
[b]after energy source

TABLE 45. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-34, SECTION 3, DECEMBER 5, 1979 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	3,421.3	1,806.0	93,670	22,968.8	5.50	47.5	13,252.5	44,750.0
5- 10	4,295.0	1,337.5	54,670	23,218.8	5.50	52.5	13,087.5	47,250.0
10- 15	3,046.3	1,493.8	74,420	1,696.9	4.75	35.0	10,262.5	24,500.0
15- 20	2,140.0	900.0	49,170	9,687.5	19.00	25.0	9,637.5	20,000.0
20- 25	1,671.3	287.2	36,670	6,595.0	6.00	22.5	6,162.5	6,000.0
40- 45	827.5	0.0	22,670	1,845.0	5.75	12.5	3,462.5	1,875.0
60- 65	827.5	50.0	18,170	1,782.5	7.75	27.5	2,712.5	1,875.0
80- 85	1,015.0	212.5	36,670	3,187.5	8.00	52.5	3,587.5	2,375.0
100-105	1,015.0	175.0	33,420	3,095.0	7.00	0.0	3,437.5	2,750.0
120-125a	858.8	46.9	30,670	2,532.5	6.50	22.5	2,812.5	1,562.5
120-125b	1,015.0	231.3	35,920	2,970.0	8.00	17.5	2,137.5	2,125.0
140-145a	890.0	12.5	21,170	1,875.0	8.25	0.0	2,612.5	2,375.0
140-145b	765.0	0.0	23,670	1,625.0	4.00	7.5	2,262.5	1,375.0

[a]before energy source
[b]after energy source

TABLE 46. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-34, SECTION 4, DECEMBER 5, 1979 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	3,265.0	1,743.8	65,670	23,093.8	5.25	57.5	8,362.5	20,500.0
5- 10	3,733.8	1,900.0	48,170	24,968.8	4.50	52.5	9,262.5	36,750.0
10- 15	4,046.3	2,087.5	87,420	25,218.8	8.75	65.0	14,337.5	27,750.0
15- 20	1,640.0	650.0	66,670	7,157.5	8.75	7.5	4,937.5	8,750.0
20- 25	983.8	112.5	34,920	3,157.5	3.50	45.0	2,312.5	1,500.0
40- 45	952.5	15.6	25,420	2,500.0	6.75	0.0	3,112.5	1,375.0
60- 65	796.3	112.5	23,420	1,470.0	7.25	37.5	2,437.5	800.0
80- 85	1,171.3	190.6	43,670	4,282.5	7.75	17.5	3,537.5	2,775.0
100-105	1,108.8	181.3	38,670	3,845.0	6.75	37.5	3,437.5	1,750.0
120-125	858.8	109.4	25,920	2,562.5	9.00	7.5	3,212.5	1,300.0
140-145	733.8	18.8	23,920	1,937.5	17.50	52.5	2,712.5	475.0

TABLE 47. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-12, SECTION 1, DECEMBER 5, 1980 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	1,373.8	88.1	34,610	2,975.0	8.87	87.5	2,537.5	3,550.0
5- 10	1,405.0	41.3	30,110	2,881.3	9.01	0.0	1,962.5	5,500.0
10- 15	1,123.8	47.5	28,360	1,618.8	8.51	37.5	2,687.5	4,350.0
15- 20	1,061.3	28.8	28,485	1,656.3	8.21	0.0	2,262.5	2,825.0
20- 25	1,092.5	63.1	20,110	1,943.8	4.26	0.0	2,537.5	1,425.0
40- 45	1,092.5	31.9	20,735	1,832.5	4.26	0.0	2,387.5	587.5
60- 65	1,123.8	88.1	31,860	2,143.8	6.08	0.0	1,462.5	4,500.0
80- 85	1,061.3	6.9	30,860	1,556.3	33.45	0.0	2,762.5	4,350.0
100-105	1,155.0	88.1	30,110	1,906.3	10.95	0.0	2,137.5	4,550.0
120-125	1,186.3	78.8	35,735	2,031.3	12.77	0.0	2,212.5	4,425.0
140-145	1,092.5	19.4	17,235	1,793.8	4.26	0.0	2,512.5	525.0

TABLE 48. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-12, SECTION 2, DECEMBER 5, 1980 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	1,201.9	144.4	34,235	2,438.1	6.67	20.0	3,837.5	2,975.0
5- 10	1,108.8	71.9	18,735	2,095.0	12.00	12.5	3,037.5	1,700.0
10- 15	1,373.8	0.0	30,985	2,356.3	4.26	5.0	4,237.5	1,725.0
15- 20	1,202.5	212.5	40,985	2,062.5	50.00	10.0	2,837.5	675.0
20- 25	1,092.5	0.0	29,985	1,668.8	5.47	0.0	2,037.5	1,950.0
40- 45	1,030.0	88.1	20,610	1,943.8	5.17	0.0	1,712.5	2,500.0
60- 65	1,046.3	115.6	14,735	1,437.5	9.00	0.0	1,812.5	2,262.5
80- 85	1,185.3	0.0	34,360	1,593.8	6.69	2.5	2,537.5	4,800.0
100-105	-	-	-	-	-	-	-	-
120-125a	905.0	0.0	21,735	1,506.3	5.78	0.0	2,062.5	600.0
120-125b	998.8	0.0	22,860	1,643.8	2.74	0.0	2,687.5	1,162.5
140-145a	780.0	13.1	28,860	1,593.8	3.95	5.0	2,412.5	750.0
140-145b	1,405.0	41.3	16,360	3,243.8	3.35	5.0	3,187.5	3,700.0

[a]before energy source
[b]after energy source

TABLE 49. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-34, SECTION 3, DECEMBER 5, 1980 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	3,874.4	1,550.0	122,050	19,657.5	12.01	193.7	10,850.0	7,900.0
5- 10	3,890.0	1,559.4	67,800	18,200.0	7.00	95.0	13,262.5	2,875.0
10- 15	2,546.3	812.5	49,550	11,250.0	18.25	42.5	7,912.5	5,800.0
15- 20	1,390.0	337.5	18,300	3,975.0	70.00	5.0	4,462.5	4,625.0
20- 25	-	-	-	-	-	-	-	-
40- 45	1,327.0	122.5	16,925	3,225.0	-	0.0	3,726.5	4,075.0
60- 65	1,140.0	37.5	41,925	2,700.0	10.75	2.5	4,337.5	1,087.5
80- 85	1,015.0	0.0	30,175	1,725.0	9.00	0.0	3,062.5	850.0
100-105	921.3	0.0	23,675	1,625.0	5.00	87.5	3,037.5	1,287.5
120-125a	905.0	0.0	15,110	1,456.3	4.87	0.0	2,262.5	600.0
120-125b	1,265.0	0.0	31,050	3,125.0	3.75	90.0	4,687.5	1,600.0
140-145a	983.8	143.8	28,925	1,532.5	5.25	15.0	1,862.5	812.5
140-145b	1,390.0	6.3	37,550	2,875.0	7.25	45.0	4,487.5	1,725.5

[a] before energy source
[b] after energy source

TABLE 50. CHEMICAL ANALYSIS OF SOIL SAMPLES TAKEN FROM BLWRS-34, SECTION 4, DECEMBER 5, 1980 - METALS, IN PPM

Depth (cm)	K	Na	Ca	Mg	Cu	Zn	Fe	Al
0- 5	2,671.3	1,056.3	100,175	16,900.0	5.75	95.0	6,537.5	3,550.0
5- 10	3,921.2	1,187.5	91,425	19,712.0	8.81	133.7	5,587.5	5,500.0
10- 15	3,108.8	981.3	58,050	15,850.0	5.25	1025.0	6,112.5	10,500.0
15- 20	4,296.3	693.8	126,300	10,850.0	-	20.0	4,462.5	4,150.0
20- 25	-	-	-	-	-	-	-	-
40- 45	1,046.3	18.8	48,800	1,937.5	5.25	22.5	2,512.5	700.0
60- 65	890.0	0.0	36,625	1,437.5	2.25	255.0	2,112.5	1,162.5
80- 85	796.3	0.0	49,925	1,500.0	2.75	52.5	2,387.5	562.5
100-105	-	-	-	-	-	-	-	-
120-125	983.8	9.4	30,925	1,595.0	4.00	52.5	2,537.5	762.5
140-145	952.5	0.0	44,800	1,875.0	2.75	0.0	2,562.5	187.5

TABLE 51. COEFFICIENTS OF DISTRIBUTION SOLUTION/SOIL FOR THE SELECTED METALS AND ORGANIC CARBON - BLWRS-12

	1979				1980			
Depth	K	Ca	Mg	C_{org}	K	Ca	Mg	C_{org}
				Section 1				
0	0.450	0.028	0.058	-	0.243	0.005	0.016	0.110
30	0.632	0.015	0.034	-	0.190	0.012	0.038	0.012
80	0.310	0.016	0.027	-	0.240	0.012	0.035	0.013
140	0.280	0.013	0.037	-	0.200	0.025	0.030	0.012
				Section 2				
0	0.560	0.043	0.120	-	0.270	0.005	0.020	0.220
30	0.280	0.011	0.024	-	0.200	0.010	0.039	0.036
80	0.400	0.017	0.027	-	0.210	0.011	0.034	0.012
140a	0.340	0.014	0.035	-	0.270	0.010	0.032	0.014
140b	0.186	0.008	0.014	-	0.190	0.010	0.036	0.022

[a]before energy source
[b]after energy source

TABLE 52. COEFFICIENTS OF DISTRIBUTION SOLUTION/SOIL FOR THE SELECTED METALS AND ORGANIC CARBON - BLWRS-34

	1979				1980			
Depth	K	Ca	Mg	C_{org}	K	Ca	Mg	C_{org}
				Section 3				
0	0.217	0.007	0.005	-	0.084	0.002	0.003	0.102
30	0.501	0.006	0.015	-	0.220	0.011	0.028	0.032
80	0.533	0.007	0.025	-	0.239	0.008	0.092	0.046
140a	0.118	0.017	0.039	-	0.164	0.009	0.095	0.018
140b	0.433	0.013	0.046	-	0.190	0.004	0.030	0.021
				Section 4				
0	0.028	0.009	0.005	-	0.122	0.002	0.003	0.122
30	0.647	0.006	0.022	-	0.279	0.004	0.047	0.042
80	0.461	0.006	0.019	-	0.305	0.005	0.106	0.040
140	0.154	0.017	0.043	-	0.197	0.006	0.088	0.011

[a]before energy source
[b]after energy source

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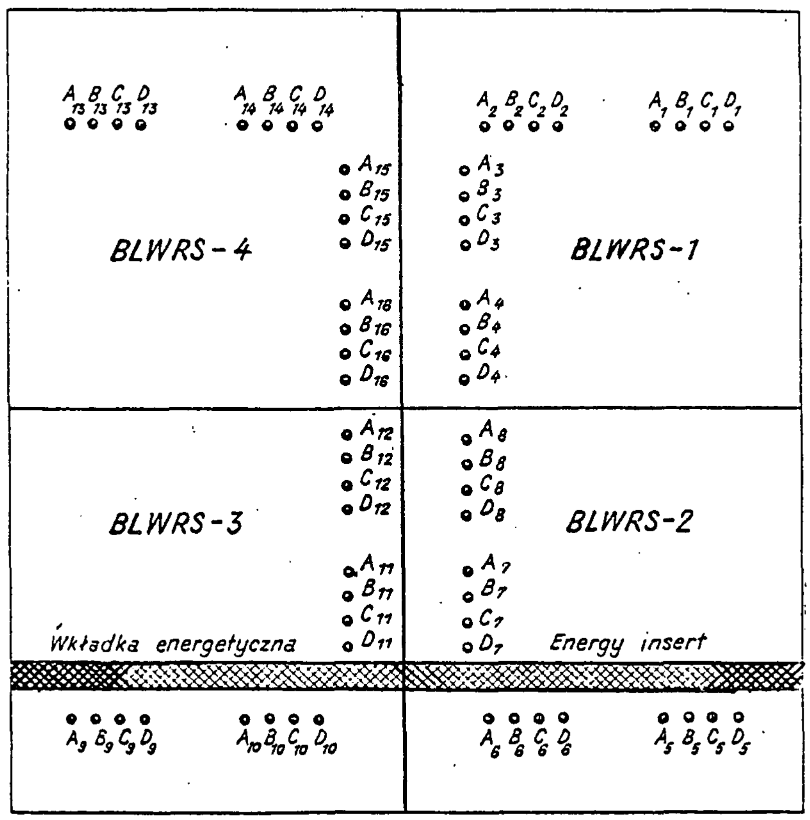
APPENDIX A

Waste samples reported herein were taken in the BLWRS according to the diagram of sampling points shown below and were averaged to form representative samples for the investigated BLWRS layer or location according to the following composition:



A - poziom 30 cm ; 30 cm level
B - poziom 80 cm ; 80 cm level
C - poziom 140 cm ; 140 cm level
D - poziom 160 cm ; 160 cm level

Sample code	Sampling points
500	pipelines introducing raw wastes after coagulation into BLWRS-12;
600	pipelines introducing raw wastes after mechanical settling tank into BLWRS-34;

518	A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8,
618	A_9, A_{10}, A_{11}, A_{12}, A_{13}, A_{14}, A_{15}, A_{16}
528	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8
628	B_9, B_{10}, B_{11}, B_{12}, B_{13}, B_{14}, B_{15}, B_{16}
136	C_1; C_2
137	C_3, C_4
146	D_1, D_2
147	D_3, D_4
236	C_5, C_6
237	C_7, C_8
246	D_5, D_6
247	D_7, D_8
336	C_9, C_{10}
337	C_{11}, C_{12}
346	D_9, D_{10}
347	D_{11}, D_{12}
436	C_{13}, C_{14}
437	C_{15}, C_{16}
446	D_{13}, D_{14}
447	D_{15}, D_{16}
105	siphon overflow in the effluent catchbasin for BLWRS-1
205	siphon overflow in the effluent catchbasin for BLWRS-2
305	siphon overflow in the effluent catchbasin for BLWRS-3
405	siphon overflow in the effluent catchbasin for BLWRS-4

TABLE A-1. CHARACTERISTICS OF WASTES APPLIED TO BLWRS (CONCENTRATION OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 500 - Raw Wastes After Coagulation - BLWRS-12
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	18	8,660.222	195.00	42,260.00	14,485.966
TKN	55	1,182.556	504.00	4,480.00	822.318
$N\text{-}NH_3$	40	535.600	107.00	987.00	132.592
$N\text{-}NO_3$	17	8.018	2.18	36.00	7.917
$N\text{-}NO_2$	17	0.295	0.00	1.16	0.304
Q Applied	128	4,192.547	0.00	9,999.00	4,090.090
COD	65	9,736.615	2,990.00	49,402.00	8,905.960
TP	17	320.782	24.00	1,700.00	414.650
Cl^-	17	195.747	140.10	261.30	38.710
pH	38	7.008	6.20	8.40	0.356
K	5	629.644	310.97	1,287.57	373.434
Na	5	457.956	253.30	1,039.50	293.907
Ca	5	925.800	146.00	2,620.00	976.151
Mg	5	207.400	50.00	484.00	174.137
Cu	5	1.242	0.36	2.84	1.067
Zn	6	11.417	1.50	31.80	10.297
Fe	5	34.000	5.50	73.60	31.935
Al	5	405.500	7.50	930.00	321.529
Cd	4	0.026	0.00	0.07	0.028
Precipitation, mm	117	1.537	0.00	11.60	2.355
Evaporation, mm	77	1.242	0.00	5.30	1.227
Soil Temp at 5cm, °C	157	9.082	-2.50	19.30	6.498
Soil Temp at 10cm, °C	157	9.324	-1.60	19.10	6.245
Soil Temp at 20cm, °C	157	9.812	0.20	19.00	5.991
Soil Temp at 50cm, °C	157	10.590	2.00	18.40	5.549
Avg. Daily Temp, °C	154	9.829	-7.90	24.00	7.293
Percent, O_2	88	56.420	40.00	73.00	6.874

TABLE A-2. CHARACTERISTICS OF WASTES APPLIED TO BLWRS (CONCENTRATION OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 600 - Raw Wastes After Setting - BLWRS-34
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	21	7,504.571	226.00	38,884.00	11,431.404
TKN	59	1,112.553	543.00	3,374.00	605.900
$N\text{-}NH_4$	45	548.022	112.00	882.00	110.114
$N\text{-}NO_3$	20	12.012	2.70	50.00	14.992
$N\text{-}NO_2$	19	0.244	0.00	0.94	0.209
Q Applied	125	4,199.896	0.00	9,999.00	4,170.954
BOD_5	1	1,592.000	1,592.00	1,592.00	0.000
COD	54	9,545.278	1,019.00	99,999.00	13,298.467
TP	21	354.486	84.00	1,760.00	367.904
Cl^-	21	195.862	138.90	289.80	42.100
pH	31	7.042	6.40	7.40	0.204
K	5	744.020	340.53	932.91	231.153
Na	5	263.474	234.40	302.40	22.082
Ca	5	623.000	173.00	1,270.00	438.871
Mg	5	111.400	59.00	185.00	46.461
Cu	5	3.380	0.68	10.20	3.689
Zn	6	22.715	1.38	78.70	27.979
Fe	5	69.240	9.80	170.00	65.274
Al	5	37.234	8.70	72.23	28.866
Cd	4	0.046	0.01	0.10	0.035

TABLE A-3. CHARACTERISTICS OF WASTES APPLIED TO BLWRS (CONCENTRATION OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 500 - Raw Wastes After Coagulation - BLWRS-12
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	25	1,120.320	72.00	5,360.00	1,101.044
TKN	186	901.960	134.40	3,556.00	469.597
$N\text{-}NH_4$	28	625.475	123.40	1,519.00	278.299
$N\text{-}NO_3$	18	13.294	0.00	120.00	28.621
$N\text{-}NO_2$	3	0.000	0.00	0.00	0.000
$P\text{-}PO_4$	14	122.536	14.00	180.00	52.625
Q Applied	260	2,933.092	0.00	5,283.00	1,673.345
C_{org}	16	2,313.062	1,125.00	3,800.00	816.216
BOD_5	4	318.000	110.00	451.00	135.486
COD	182	4,844.060	165.00	11,820.00	1,769.181
TP	25	126.268	3.80	204.80	47.887
Cl^-	27	137.926	56.60	226.90	45.819
pH	21	7.043	6.00	8.50	0.473
K	14	334.143	165.00	488.50	68.240
Na	14	86.986	55.50	160.50	26.890
Ca	14	172.021	90.00	400.00	86.344
Mg	14	49.571	21.50	86.50	15.592
Cu	12	0.330	0.16	0.56	0.122
Zn	14	1.661	0.50	3.40	0.782
Fe	12	6.317	1.50	19.10	4.652
Al	13	6.932	0.60	42.75	10.786
Precipitation, mm	262	2.920	0.00	30.00	4.243
Evaporation, mm	201	1.691	0.70	3.00	0.590
Soil Temp at 5cm, °C	262	9.026	-2.50	19.50	5.615
Soil Temp at 10cm, °C	262	9.177	-1.50	19.10	5.527
Soil Temp at 20cm, °C	262	9.352	0.20	19.00	5.346
Soil Temp at 50cm, °C	262	9.946	1.90	19.00	5.187
Avg. Daily Temp, °C	262	10.327	-4.10	24.00	6.124
Soil O_2, Percent Saturation	161	56.652	32.00	82.00	10.371

TABLE A-4. CHARACTERISTICS OF WASTES APPLIED TO BLWRS (CONCENTRATION OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 600 - Raw Wastes After Setting - BLWRS-34
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	26	1,041.808	78.00	4,210.00	1,112.336
TKN	184	961.121	112.00	4,452.00	590.810
$N\text{-}NH_4$	28	677.714	195.00	1,234.80	249.973
$N\text{-}NO_3$	14	4.432	0.00	12.00	3.477
$N\text{-}NO_2$	1	0.000	0.00	0.00	0.000
$P\text{-}PO_4$	14	119.943	16.00	172.80	48.582
Q Applied	260	2,898.562	0.00	6,126.00	1,712.861
C_{org}	16	2,448.687	1,340.00	5,400.00	1,056.316
BOD_5	4	425.375	112.50	883.00	285.817
COD	179	6,487.997	465.00	68,646.00	9,862.353
TP	25	143.372	5.30	432.00	74.530
Cl^-	26	137.408	28.30	222.20	48.274
pH	21	6.976	6.10	7.60	0.364
K	14	327.000	170.00	415.00	60.490
Na	14	91.607	62.50	161.00	25.364
Ca	14	185.736	85.00	460.00	109.843
Mg	14	50.200	28.00	65.00	10.875
Cu	12	0.440	0.22	1.24	0.285
Zn	14	1.579	0.20	3.30	0.929
Fe	12	7.717	2.60	19.60	5.397
Al	14	6.194	1.90	25.60	5.925

TABLE A-5. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 105 - Effluent from BLWRS-1
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	81.865	6.00	570.00	99.594
TKN	105	104.629	22.40	798.00	92.767
$N-NH_4$	64	57.487	0.00	210.00	34.139
$N-NO_3$	37	105.836	1.75	222.50	70.517
$N-NO_2$	36	6.750	0.04	24.00	5.040
Q Applied	7	0.000	0.00	0.00	0.000
Q Drained	138	1,754.993	218.00	9,562.00	1,242.811
BOD_5	5	41.200	10.00	98.00	32.701
COD	99	281.222	71.00	1,080.00	170.611
TP	33	2.005	0.30	11.60	1.962
Cl^-	33	159.845	80.00	214.80	35.228
pH	35	7.077	6.60	7.80	0.251
K	4	203.998	129.79	283.99	61.227
Na	4	263.658	155.93	378.00	79.263
Ca	4	423.875	328.00	490.00	59.498
Mg	4	72.325	53.30	89.50	14.096
Cu	4	0.318	0.15	0.44	0.134
Zn	4	0.388	0.18	0.74	0.212
Fe	4	9.675	3.90	19.00	6.013
Al	4	101.527	2.40	160.20	60.966
Cd	3	0.006	0.00	0.01	0.003

TABLE A-6. CHARACTERISTICS OF BLWRS EFFLUENTS. (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 205 - Effluent from BLWRS-2
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	33	206.394	16.00	1,300.00	267.249
TKN	109	155.821	23.24	1,708.00	169.809
N-NH_4	63	80.927	0.00	309.40	56.590
N-NO_3	39	78.960	0.80	260.00	76.046
N-NO_2	36	13.579	0.04	45.60	13.591
Q Drained	138	1,711.580	286.00	9,781.00	1,294.073
BOD_5	4	122.500	46.00	296.00	100.830
COD	105	551.181	99.00	1,960.00	452.972
TP	34	2.704	0.50	15.80	3.089
Cl^-	34	166.988	97.70	207.50	28.226
pH	35	7.314	6.40	7.80	0.327
K	6	180.993	70.80	299.40	83.586
Na	6	260.673	189.00	415.80	72.513
Ca	6	340.000	218.00	410.00	81.851
Mg	6	61.133	52.50	74.00	7.410
Cu	6	0.252	0.16	0.35	0.082
Zn	7	0.891	0.10	3.02	1.041
Fe	6	24.467	9.00	41.60	10.803
Al	6	89.905	0.70	210.93	65.334
Cd	5	0.004	0.00	0.01	0.002

TABLE A-7. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 305 - Effluent Catchbasin - BLWRS-3
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	123.281	8.00	610.00	148.656
TKN	107	93.497	24.00	299.60	43.660
$N-NH_4$	65	62.603	0.00	203.00	28.935
$N-NO_3$	37	101.069	1.45	430.00	78.502
$N-NO_2$	35	3.423	0.06	11.40	3.130
Q Applied	7	0.000	0.00	0.00	0.000
Q Drained	138	1,529.797	500.00	9,714.00	983.434
BOD_5	7	60.571	2.00	188.00	56.609
COD	111	291.685	87.00	1,468.00	216.213
TP	33	1.914	0.67	5.20	1.244
Cl^-	34	173.744	117.20	537.10	66.731
pH	37	7.381	6.20	7.90	0.372
K	5	210.608	92.52	295.55	75.498
Na	5	261.482	217.35	349.65	46.971
Ca	5	306.400	260.00	350.00	33.643
Mg	5	74.660	48.80	96.00	19.022
Cu	5	0.316	0.19	0.40	0.079
Zn	6	0.657	0.10	1.72	0.546
Fe	5	28.880	4.00	71.00	22.468
Al	5	5.420	2.10	8.69	2.450
Cd	4	0.004	0.00	0.01	0.002

TABLE A-8. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 405 - Effluent Catchbasin - BLWRS-4
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	30	89.830	5.00	801.00	150.742
TKN	106	80.267	0.00	322.00	66.047
$N\text{-}NH_4$	57	44.758	0.00	257.60	50.536
$N\text{-}NO_3$	34	102.274	0.00	257.50	77.410
$N\text{-}NO_2$	32	6.267	0.08	17.40	5.341
Q Applied	6	0.000	0.00	0.00	0.000
Q Drained	138	1,484.188	286.00	9,714.00	1,177.964
BOD_5	5	39.600	10.00	123.00	42.027
COD	104	260.827	67.00	1,725.00	300.415
TP	29	1.460	0.30	5.30	1.239
Cl^-	31	162.768	93.00	193.70	27.173
pH	38	7.529	6.80	7.90	0.360
K	6	150.072	61.94	327.70	92.556
Na	6	273.745	160.65	567.00	136.857
Ca	6	335.750	200.00	430.00	85.198
Mg	6	55.800	33.00	78.50	17.698
Cu	6	0.392	0.20	0.59	0.116
Zn	6	0.402	0.17	1.09	0.323
Fe	6	5.650	3.60	10.30	2.504
Al	6	4.220	2.00	10.29	2.858
Cd	5	0.003	0.00	0.01	0.002

TABLE A-9. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 105 - Effluent Catchbasin - BLWRS-1
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	33	54.667	4.00	220.00	44.382
TKN	229	121.429	16.80	688.80	87.862
$N\text{-}NH_4$	35	107.526	21.00	445.20	90.374
$N\text{-}NO_3$	37	197.297	16.00	520.00	123.784
$N\text{-}NO_2$	35	19.478	0.52	196.00	36.498
$P\text{-}PO_4$	20	7.600	0.50	52.50	15.328
Q Drained	258	1,501.054	520.00	2,785.00	425.809
C_{org}	22	214.773	42.50	1,450.00	389.818
BOD_5	4	29.625	22.00	40.00	7.676
COD	227	298.960	32.00	2,726.00	352.180
TP	33	5.879	0.40	52.50	13.157
Cl^-	37	117.824	22.50	182.10	30.588
pH	23	6.865	6.10	7.40	0.320
K	16	207.469	145.00	280.00	40.631
Na	16	67.956	37.50	107.50	21.577
Ca	16	364.188	230.00	605.00	97.673
Mg	16	48.631	32.80	67.50	9.223
Cu	15	0.294	0.07	0.90	0.224
Zn	15	0.590	0.10	1.25	0.334
Fe	15	5.940	1.50	14.60	3.580
Al	15	5.549	1.02	18.42	4.625

TABLE A-10. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 205 - Effluent Catchbasin - BLWRS-2
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	122.176	26.00	1,120.00	192.978
TKN	229	226.126	28.00	834.40	113.691
$N\text{-}NH_4$	35	195.511	53.20	588.00	117.099
$N\text{-}NO_3^-$	37	78.635	3.80	670.00	109.683
$N\text{-}NO_2^-$	35	12.387	0.15	35.84	9.515
$P\text{-}PO_4$	21	8.286	1.10	46.00	11.961
Q Drained	258	1,488.178	520.00	2,394.00	442.451
C_{org}	21	223.714	80.00	1,425.00	279.218
BOD_5	4	38.500	14.00	75.00	23.476
COD	227	470.392	111.00	2,672.00	388.661
TP	33	6.661	0.70	55.50	12.492
Cl^-	36	125.817	24.80	213.60	35.481
pH	23	7.035	6.20	7.60	0.333
K	15	235.667	172.50	368.00	50.929
Na	15	77.747	56.00	114.00	13.397
Ca	15	302.433	130.00	515.00	104.336
Mg	15	52.940	23.80	95.50	19.253
Cu	15	0.241	0.07	0.40	0.125
Zn	15	0.493	0.00	1.25	0.352
Fe	16	14.900	1.00	89.80	21.129
Al	16	2.837	0.42	11.12	2.806

TABLE A-11. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 305 - Effluent Catchbasin - BLWRS-3
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	122.781	3.00	400.00	80.762
TKN	225	246.649	25.20	812.00	121.297
$N\text{-}NH_4$	34	213.003	23.60	694.40	130.072
$N\text{-}NO_3$	36	97.717	1.00	365.00	93.665
$N\text{-}NO_2$	34	9.418	0.30	57.60	11.092
$P\text{-}PO_4$	20	6.146	0.52	36.00	9.268
Q Drained	258	1,497.326	698.00	2,819.00	425.477
C_{org}	20	257.850	36.00	1,225.00	306.519
BOD_5	4	47.875	16.00	88.00	26.520
COD	225	443.849	80.00	2,800.00	382.161
TP	32	6.741	0.50	51.00	11.763
Cl^-	35	141.460	40.50	205.50	31.067
pH	22	7.082	6.10	7.50	0.327
K	15	232.900	177.00	305.00	34.698
Na	15	102.120	57.50	179.50	34.644
Ca	16	276.469	95.00	995.00	204.070
Mg	16	114.631	47.50	290.00	55.113
Cu	15	0.483	0.09	3.75	0.888
Zn	16	0.612	0.05	1.70	0.484
Fe	15	12.693	3.40	40.70	9.588
Al	14	2.942	0.22	9.10	2.447

TABLE A-12. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 405 - Effluent Catchbasin - BLWRS-4
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	122.882	5.00	1,528.00	326.389
TKN	227	115.897	8.40	845.60	142.940
$N-NH_4$	35	119.971	22.40	660.80	145.567
$N-NO_3$	37	150.976	19.00	325.00	96.505
$N-NO_2$	35	9.742	0.55	34.40	8.775
$P-PO_4$	24	16.813	0.30	136.00	32.908
Q Drained	258	1,477.942	652.00	2,523.00	457.023
C_{org}	19	281.737	44.50	2,125.00	532.699
BOD_5	4	30.750	2.00	65.00	25.460
COD	224	269.697	25.00	2,996.00	364.011
TP	34	10.835	0.30	150.00	28.969
Cl^-	37	135.178	27.00	319.50	43.661
pH	24	7.017	6.10	7.70	0.420
K	15	200.233	50.00	395.00	79.138
Na	15	95.067	57.50	164.00	30.765
Ca	15	254.433	130.00	540.00	108.722
Mg	15	114.833	47.00	220.00	43.741
Cu	14	0.289	0.11	0.88	0.188
Zn	15	0.533	0.05	1.55	0.408
Fe	14	6.421	1.70	22.00	5.233
Al	15	4.279	0.02	22.80	5.763

TABLE A-13. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 105 - Effluent Catchbasin - BLWRS-1
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	7	376.429	30.00	732.00	254.292
TKN	70	185.983	0.00	604.80	168.667
N-NH_4	5	232.400	47.60	291.20	93.152
N-NO_3	9	80.222	0.00	520.00	158.414
N-NO_2	9	0.811	0.00	2.70	0.977
P-PO_4	8	24.462	7.20	52.00	14.962
C_{org}	5	364.000	85.00	665.00	234.657
COD	70	703.586	51.00	3,065.00	691.936
TP	8	26.650	8.20	52.50	14.491
Cl^-	9	99.378	72.70	145.40	23.248
pH	3	7.633	6.80	8.20	0.602
K	4	207.000	145.50	237.00	36.078
Na	4	44.875	37.00	49.50	4.827
Ca	4	165.000	10.00	280.00	101.550
Mg	4	49.750	46.00	54.00	2.839
Cu	4	0.130	0.02	0.31	0.111
Zn	4	0.400	0.20	0.70	0.197
Fe	4	6.822	0.63	19.17	7.557
Al	4	1.518	0.75	2.00	0.492

TABLE A-14. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 205 - Effluent Catchbasin - BLWRS-2
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	7	443.000	15.00	870.00	301.900
TKN	70	277.814	33.60	697.20	155.884
$N\text{-}NH_4$	5	193.200	84.00	322.00	93.773
$N\text{-}NO_3$	9	62.222	0.00	420.00	129.681
$N\text{-}NO_2$	9	6.100	0.00	47.20	14.640
$P\text{-}PO_4$	8	28.425	12.00	42.00	10.126
C_{org}	7	281.286	75.00	420.00	124.705
COD	72	776.986	137.00	3,424.00	709.306
TP	8	33.375	17.50	43.00	9.310
Cl^-	9	95.689	72.10	137.20	17.930
pH	3	7.800	7.40	8.30	0.374
K	4	210.625	157.50	258.50	41.174
Na	4	49.125	34.50	60.50	10.328
Ca	4	128.750	95.00	215.00	50.172
Mg	4	50.500	45.50	55.50	4.528
Cu	3	0.067	0.03	0.11	0.033
Zn	4	0.925	0.15	1.90	0.656
Fe	3	3.177	2.63	4.19	0.717
Al	3	1.167	0.16	1.80	0.720

TABLE A-15. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 305 - Effluent Catchbasin - BLWRS-3
Time Period -01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	7	522.857	150.00	900.00	275.284
TKN	70	251.360	39.20	456.40	108.445
$N\text{-}NH_4$	5	227.800	100.20	333.20	82.765
$N\text{-}NO_3$	9	33.333	0.00	180.00	57.542
$N\text{-}NO_2$	9	2.467	0.00	10.80	3.370
$P\text{-}PO_4$	8	34.713	15.00	56.00	14.080
C_{org}	7	469.143	250.00	685.00	141.906
COD	70	805.357	93.00	2,621.00	672.151
TP	8	38.587	22.00	57.00	11.424
Cl-	9	98.300	84.20	122.50	11.115
pH	2	8.100	7.80	8.40	0.300
K	4	207.000	131.50	344.50	81.995
Na	4	59.250	43.50	76.00	14.188
Ca	4	308.750	85.00	945.00	367.447
Mg	4	71.625	31.50	141.00	41.384
Cu	3	0.187	0.14	0.28	0.066
Zn	4	0.788	0.35	1.35	0.359
Fe	3	7.840	6.28	9.06	1.160
Al	3	4.023	0.82	9.45	3.858

TABLE A-16. CHARACTERISTICS OF BLWRS EFFLUENTS (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 405 - Effluent Catchbasin - BLWRS-4
Time Period -01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	5	1,110.800	664.00	1,900.00	415.503
TKN	67	551.397	0.00	893.20	254.682
$N-NH_4$	3	560.000	518.00	588.00	30.243
$N-NO_3$	6	2.500	0.00	15.00	5.590
$N-NO_2$	7	0.271	0.00	0.70	0.271
$P-PO_4$	6	49.500	27.00	70.00	16.480
C_{org}	5	1,672.500	1,072.50	2,250.00	394.987
COD	67	2,791.306	109.00	6,013.00	1,465.784
TP	6	53.583	36.00	74.00	16.265
Cl^-	7	118.314	74.80	161.70	26.119
pH	2	7.600	7.20	8.00	0.400
K	3	249.667	231.00	264.50	13.942
Na	3	75.333	49.00	104.50	22.746
Ca	3	118.333	60.00	160.00	42.492
Mg	3	45.333	43.00	47.00	1.700
Cu	3	0.250	0.09	0.36	0.116
Zn	3	0.783	0.35	1.50	0.510
Fe	3	4.960	4.38	5.80	0.608
Al	3	8.313	5.00	10.92	2.468

TABLE A-17. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 518 - 30 cm Depth, Eight Points in BLWRS-12
Time Period -01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	25	533.520	62.00	4,600.00	901.212
TKN	25	499.184	61.60	1,366.40	286.042
$N\text{-}NH_4$	26	322.169	23.80	900.00	186.692
$N\text{-}NO_3$	27	64.375	1.75	225.00	76.405
$N\text{-}NO_2$	26	10.479	0.00	91.20	21.551
BOD_5	3	335.000	66.00	799.00	329.485
COD	29	1,517.655	392.00	3,380.00	751.796
TP	27	34.507	13.40	61.60	13.756
Cl^-	24	197.421	46.30	322.20	61.477
pH	35	7.440	6.50	7.90	0.316
K	7	651.247	269.85	1,518.87	391.731
Na	7	291.134	134.20	774.90	205.423
Ca	7	333.857	153.00	1,230.00	366.473
Mg	7	60.643	30.00	175.00	47.350
Cu	7	0.450	0.29	1.03	0.243
Zn	7	1.041	0.31	2.92	0.851
Fe	7	8.600	2.00	14.30	4.024
Al	7	141.653	1.30	500.62	159.628
Cd	5	0.007	0.00	0.02	0.008

TABLE A-18. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 528 - 80 cm Depth, Eight Points in BLWRS-12
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	25	275.796	25.00	701.00	173.899
TKN	23	423.930	156.80	1,092.00	226.300
$N\text{-}NH_4$	26	305.185	53.20	942.00	220.175
$N\text{-}NO_3$	26	75.429	1.90	385.30	98.230
$N\text{-}NO_2$	25	48.881	0.00	156.80	53.775
BOD_5	2	46.000	30.00	62.00	16.000
COD	30	1,261.033	320.00	3,809.00	915.191
TP	25	21.248	4.50	63.00	13.993
Cl^-	24	218.475	143.50	314.80	43.645
pH	36	7.369	6.40	7.90	0.289
K	5	355.944	298.12	496.00	72.277
Na	5	310.332	158.76	812.70	252.226
Ca	5	380.800	95.00	930.00	296.927
Mg	5	57.400	24.00	153.00	48.102
Cu	5	0.518	0.31	1.14	0.313
Zn	5	1.058	0.49	2.97	0.961
Fe	5	8.600	3.10	14.70	4.452
Al	5	105.010	5.80	200.25	73.511
Cd	4	0.003	0.00	0.01	0.002

TABLE A-19. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 618 - 30 cm Depth, Eight Points in BLWRS-34
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	13	1,124.384	57.00	3,681.00	604.255
TKN	18	502.006	112.00	1,904.00	396.479
$N-NH_4$	18	179.094	26.30	336.00	85.715
$N-NO_3$	15	64.069	2.18	216.00	50.425
$N-NO_2$	14	9.624	0.26	62.40	15.100
BOD_5	1	393.000	393.00	393.00	0.000
COD	20	1,698.250	103.00	4,959.00	1,345.048
TP	16	36.987	9.80	60.00	18.748
Cl^-	13	182.031	46.30	299.20	55.790
pH	33	7.824	7.10	8.80	0.392
K	4	623.708	257.00	1,038.28	324.354
Na	4	267.440	192.80	336.42	53.325
Ca	4	186.500	120.00	263.00	54.656
Mg	4	62.200	48.00	82.80	12.733
Cu	4	0.472	0.33	0.68	0.137
Zn	4	1.005	0.55	1.74	0.445
Fe	4	6.475	2.50	8.80	2.385
Al	4	6.255	4.50	9.28	1.806
Cd	3	0.001	0.00	0.00	0.001

TABLE A-20. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 628 - 80 cm Depth, Eight Points in BLWRS-34
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	12	656.917	112.00	2,264.00	573.847
TKN	13	291.208	72.80	616.00	152.636
$N-NH_4$	13	128.969	0.00	285.60	85.995
$N-NO_3$	12	100.658	4.30	332.00	103.174
$N-NO_2$	12	2.709	0.11	15.36	3.942
BOD_5	1	210.000	210.00	210.00	0.000
COD	14	1,215.929	283.00	2,520.00	708.239
TP	10	40.560	16.40	70.50	15.389
Cl^-	11	177.100	70.50	282.00	56.219
pH	31	7.774	7.00	8.30	0.314
K	3	540.557	416.34	683.62	109.927
Na	3	517.860	228.69	869.40	265.261
Ca	3	271.333	190.00	416.00	102.558
Mg	3	80.000	47.00	136.00	39.808
Cu	3	0.720	0.48	0.93	0.185
Zn	3	4.243	1.35	10.00	4.071
Fe	3	11.267	9.90	13.90	1.862
Al	3	11.780	10.00	14.00	1.662
Cd	3	0.018	0.00	0.03	0.014

TABLE A-21. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 136 - 140 cm Depth, Two Points in BLWRS-1
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	363.742	86.00	1,873.00	353.513
TKN	33	107.661	14.00	408.80	101.017
$N-NH_4$	33	59.579	0.00	281.00	71.223
$N-NO_3$	35	100.233	1.90	830.00	143.639
$N-NO_2$	33	22.384	0.06	320.00	55.769
BOD_5	3	65.000	11.00	107.00	40.100
COD	30	505.633	87.00	2,153.00	495.277
TP	31	5.866	0.60	70.50	12.466
Cl^-	32	168.197	103.70	214.80	28.181
pH	35	7.580	7.10	8.10	0.200
K	6	238.585	52.69	438.20	180.422
Na	6	240.657	174.83	321.30	43.838
Ca	6	338.167	128.00	495.00	138.242
Mg	6	60.583	53.00	69.00	6.214
Cu	5	0.356	0.18	0.58	0.137
Zn	5	0.746	0.50	1.32	0.307
Fe	5	22.520	4.40	37.80	13.211
Al	5	94.766	2.70	160.20	51.371
Cd	4	0.015	0.00	0.05	0.019

TABLE A-22. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 137 - 140 cm Depth, Two Points in BLWRS-1
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	30	252.400	46.00	848.00	226.207
TKN	36	195.267	56.00	336.00	82.971
$N\text{-}NH_4$	35	130.126	0.00	310.80	77.983
$N\text{-}NO_3$	35	139.459	2.30	430.00	138.275
$N\text{-}NO_2$	31	27.181	0.09	130.40	33.485
BOD_5	4	107.500	1.00	415.00	177.603
COD	32	355.500	120.00	1,342.00	289.746
TP	32	3.719	1.40	9.80	1.798
Cl^-	30	215.563	123.20	270.50	36.336
pH	38	7.329	6.80	7.60	0.215
K	6	364.682	151.63	524.28	145.488
Na	6	300.978	221.10	434.70	79.286
Ca	6	369.750	305.00	458.50	53.746
Mg	6	67.300	43.80	88.00	13.624
Cu	6	0.343	0.27	0.44	0.056
Zn	6	0.668	0.22	1.01	0.336
Fe	5	18.580	2.80	49.80	16.299
Al	6	92.350	4.30	154.86	45.069
Cd	5	0.006	0.00	0.02	0.005

TABLE A-23. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 146 - 160 cm Depth, Two Points in BLWRS-1
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	36	296.306	27.00	1,242.00	269.650
TKN	37	58.892	6.00	207.20	45.075
$N\text{-}NH_4$	36	24.281	0.00	103.60	28.040
$N\text{-}NO_3$	40	73.221	0.53	216.00	67.849
$N\text{-}NO_2$	38	10.532	0.05	48.80	12.755
BOD_5	2	86.500	56.00	117.00	30.500
COD	34	364.250	99.00	1,760.00	347.573
TP	36	2.516	0.60	7.20	1.600
Cl^-	36	159.586	46.50	228.10	46.722
pH	46	7.374	6.40	8.40	0.318
K	6	143.235	35.79	380.40	125.970
Na	6	229.395	119.55	302.40	64.318
Ca	6	440.000	365.00	565.00	68.618
Mg	6	206.217	52.00	925.00	321.537
Cu	6	0.348	0.24	0.41	0.054
Zn	6	0.577	0.43	0.90	0.159
Fe	6	19.300	4.50	36.80	14.384
Al	6	74.388	4.40	141.51	51.195
Cd	4	0.004	0.00	0.01	0.001

TABLE A-24. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 147 - 160 cm Depth, Two Locations in BLWRS - 1
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	293.294	48.00	1,248.00	319.997
TKN	38	153.539	31.00	336.00	81.790
$N\text{-}NH_4$	37	98.368	0.00	243.60	59.046
$N\text{-}NO_3$	38	127.859	0.00	425.50	129.462
$N\text{-}NO_2$	38	25.532	0.04	86.40	27.995
BOD_5	3	103.667	3.00	299.00	138.143
COD	35	349.194	61.00	2,032.00	433.629
TP	36	2.876	1.00	7.00	1.769
Cl^-	36	210.333	123.20	330.90	38.665
pH	47	7.317	6.30	7.70	0.285
K	7	368.613	125.29	616.80	192.160
Na	7	318.459	217.35	529.20	92.955
Ca	7	453.857	305.00	615.00	98.636
Mg	7	83.471	54.30	142.50	26.221
Cu	7	0.364	0.12	0.61	0.141
Zn	7	0.666	0.32	1.52	0.387
Fe	7	19.486	4.00	59.50	18.713
Al	7	108.059	7.70	218.94	77.170
Cd	5	0.006	0.00	0.01	0.003

TABLE A-25. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 236 - 140 cm Depth, Two Points in BLWRS -2
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	497.176	51.00	1,282.00	268.302
TKN	37	210.222	50.00	568.40	130.317
$N\text{-}NH_4$	37	131.551	0.00	481.60	108.037
$N\text{-}NO_3$	37	28.470	0.50	440.00	77.549
$N\text{-}NO_2$	36	1.653	0.00	14.40	3.183
BOD_5	4	419.375	129.50	744.00	235.459
COD	34	915.353	182.00	2,920.00	563.444
TP	33	4.452	1.70	9.20	2.207
Cl^-	35	147.880	29.60	188.60	32.668
pH	40	7.193	6.40	7.60	0.268
K	6	212.092	63.99	359.80	104.626
Na	6	165.170	96.10	245.70	53.631
Ca	6	272.500	107.00	360.00	86.569
Mg	6	43.467	14.50	55.50	14.538
Cu	6	0.417	0.19	0.80	0.191
Zn	7	1.007	0.27	3.24	0.937
Fe	6	57.250	14.40	109.00	34.719
Al	6	83.173	1.40	156.20	45.243
Cd	5	0.011	0.00	0.03	0.008

TABLE A-26. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 237 - 140 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	226.971	10.00	772.00	223.414
TKN	38	147.437	30.80	384.00	79.435
$N\text{-}NH_4$	38	106.189	0.00	245.00	62.761
$N\text{-}NO_3$	38	66.739	5.10	305.00	64.706
$N\text{-}NO_2$	36	19.963	0.09	88.00	20.546
BOD_5	1	431.000	431.00	431.00	0.000
COD	35	244.400	73.00	823.00	147.612
TP	36	2.724	0.60	7.30	1.826
Cl^-	35	179.034	69.80	240.80	40.063
pH	37	7.251	6.40	7.80	0.315
K	5	293.820	213.95	466.46	89.531
Na	5	284.266	170.10	519.75	121.561
Ca	5	383.500	226.00	765.00	200.143
Mg	5	75.560	43.00	160.50	42.922
Cu	5	0.344	0.19	0.49	0.112
Zn	5	0.612	0.22	1.10	0.290
Fe	5	22.820	4.70	50.50	15.522
Al	5	91.170	11.10	181.56	65.223
Cd	4	0.006	0.01	0.01	0.001

TABLE A-27. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 246 - 160 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	36	669.361	63.00	2,822.00	583.703
TKN	37	172.138	64.40	543.60	111.503
$N-NH_4$	38	90.492	0.00	240.80	54.260
$N-NO_3$	40	23.403	0.15	396.00	63.635
$N-NO_2$	38	0.630	0.00	3.20	0.733
BOD_5	4	267.250	69.00	591.00	201.204
COD	35	868.029	158.00	3,360.00	612.669
TP	36	4.467	1.40	8.00	1.821
Cl^-	36	152.386	65.10	212.70	33.927
pH	40	7.142	6.10	8.00	0.402
K	6	181.507	94.45	327.68	79.514
Na	6	219.482	104.42	308.10	77.534
Ca	6	401.750	260.00	540.50	99.391
Mg	6	60.633	39.00	87.00	16.287
Cu	6	0.337	0.18	0.41	0.078
Zn	6	0.647	0.34	0.95	0.226
Fe	6	61.200	13.30	102.00	30.822
Al	6	101.167	13.50	173.55	52.389
Cd	5	0.005	0.00	0.01	0.001

TABLE A-28. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 247 - 160 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	36	338.306	55.00	2,042.00	381.002
TKN	36	167.128	35.00	565.00	94.181
$N\text{-}NH_4$	38	112.971	0.00	336.00	64.581
$N\text{-}NO_3$	40	82.245	0.30	244.00	80.446
$N\text{-}NO_2$	38	15.602	0.04	146.40	28.792
BOD_5	2	335.250	119.50	551.00	215.750
COD	35	468.171	153.00	1,890.00	390.217
TP	36	3.412	1.10	9.30	1.927
Cl^-	36	185.811	47.70	243.10	40.634
pH	45	7.140	6.20	7.70	0.272
K	6	243.717	95.73	412.49	118.531
Na	6	267.597	213.57	396.90	61.522
Ca	6	410.167	300.00	545.00	84.864
Mg	6	72.350	44.50	99.00	16.414
Cu	6	0.395	0.25	0.62	0.119
Zn	5	0.860	0.55	1.64	0.396
Fe	6	35.250	8.00	73.50	21.741
Al	6	90.447	4.40	162.87	64.145
Cd	4	0.007	0.00	0.01	0.004

TABLE A-29. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 336 - 140 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	30	410.633	86.00	1,136.00	294.835
TKN	26	193.854	106.40	448.00	69.920
$N-NH_4$	31	141.368	16.80	378.00	77.031
$N-NO_3$	33	66.632	1.45	220.00	63.066
$N-NO_2$	32	5.825	0.06	51.20	11.118
BOD_5	4	246.000	25.00	765.00	302.098
COD	29	699.069	163.00	3,294.00	676.678
TP	29	6.942	1.40	15.30	3.805
Cl^-	31	169.832	112.70	206.30	26.799
pH	31	7.516	6.60	7.90	0.264
K	5	330.880	105.37	463.89	127.379
Na	5	247.784	190.89	302.40	38.083
Ca	5	308.000	250.00	465.00	79.912
Mg	5	74.100	57.50	83.50	9.378
Cu	5	0.580	0.26	1.07	0.309
Zn	5	1.456	0.35	4.10	1.378
Fe	5	17.460	6.20	26.50	8.980
Al	5	11.116	3.24	30.50	9.902
Cd	4	0.007	0.00	0.01	0.002

TABLE A-30. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 337 - 140 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	35	291.971	44.00	2,341.00	396.187
TKN	34	66.735	8.40	176.00	41.826
$N\text{-}NH_4$	36	46.361	0.00	195.00	48.982
$N\text{-}NO_3$	39	167.222	4.10	487.00	127.128
$N\text{-}NO_2$	35	3.648	0.10	14.10	3.161
BOD_5	3	47.000	1.00	136.00	62.944
COD	34	180.176	62.00	813.00	168.893
TP	35	4.367	0.50	24.30	5.276
Cl^-	34	215.709	67.40	1,541.00	232.924
pH	34	7.638	6.60	8.50	0.384
K	6	104.713	46.90	169.62	42.466
Na	6	275.155	218.30	330.75	41.530
Ca	6	357.083	260.00	467.50	63.940
Mg	6	72.417	48.00	108.50	20.460
Cu	6	0.347	0.27	0.64	0.132
Zn	6	0.515	0.25	1.03	0.281
Fe	6	10.483	3.30	31.50	9.847
Al	6	7.538	4.03	13.30	3.253
Cd	5	0.004	0.00	0.01	0.003

TABLE A-31. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 346 - 160 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	33	325.879	41.00	1,954.00	364.504
TKN	35	90.006	8.40	168.00	31.812
$N\text{-}NH_4$	33	57.352	8.00	120.00	27.867
$N\text{-}NO_3$	37	83.532	1.35	257.50	79.764
$N\text{-}NO_2$	34	3.116	0.06	22.40	4.346
BOD_5	3	159.333	14.00	380.00	158.630
COD	35	323.177	33.00	1,365.00	302.448
TP	32	5.103	0.80	24.00	5.651
Cl^-	32	138.616	82.50	198.00	34.415
pH	43	7.516	6.40	8.00	0.340
K	7	149.430	74.50	283.99	64.290
Na	7	224.106	132.30	387.45	78.821
Ca	7	284.357	203.00	360.00	48.515
Mg	7	63.286	29.50	93.50	19.801
Cu	7	0.271	0.19	0.38	0.057
Zn	8	0.847	0.35	2.96	0.819
Fe	7	17.629	4.90	30.60	9.063
Al	7	4.579	3.20	7.04	1.403
Cd	5	0.002	0.00	0.00	0.002

TABLE A-32. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 347 - 160 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	35	193.943	17.00	754.00	184.747
TKN	35	48.966	0.00	148.40	36.183
$N\text{-}NH_4$	37	31.932	0.00	237.00	38.949
$N\text{-}NO_3$	39	191.429	52.00	445.00	113.410
$N\text{-}NO_2$	37	4.634	0.26	14.52	3.492
BOD_5	3	49.000	6.00	127.00	55.251
COD	37	163.400	48.00	1,024.00	185.554
TP	35	2.949	0.70	11.00	2.273
Cl^-	35	167.434	62.80	212.20	36.840
pH	45	7.496	6.30	8.50	0.423
K	6	94.123	60.40	186.30	43.913
Na	6	248.778	168.68	311.85	48.158
Ca	6	394.167	315.00	490.00	67.046
Mg	6	70.517	47.30	88.00	14.595
Cu	6	0.395	0.26	0.76	0.180
Zn	7	1.151	0.36	3.30	0.949
Fe	6	11.383	3.30	27.00	7.678
Al	6	6.135	3.06	9.50	2.006
Cd	5	0.003	0.00	0.01	0.002

TABLE A-33. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 436 - 140 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	265.419	59.00	949.00	201.823
TKN	33	41.167	11.20	188.00	35.314
$N-NH_4$	34	16.318	0.00	63.00	17.057
$N-NO_3$	35	191.121	23.50	587.50	131.800
$N-NO_2$	33	13.103	0.20	160.00	29.195
BOD_5	3	28.000	15.00	47.00	13.736
COD	32	169.281	40.00	677.00	120.364
TP	35	3.106	0.90	10.80	1.980
Cl^-	32	183.556	128.40	527.80	66.913
pH	39	7.521	6.60	8.20	0.329
K	4	107.558	66.50	134.93	25.725
Na	4	264.130	212.62	342.10	50.607
Ca	4	477.250	358.00	590.00	92.896
Mg	4	84.375	53.50	113.50	21.761
Cu	4	0.348	0.24	0.54	0.119
Zn	5	1.228	0.35	3.60	1.210
Fe	4	12.475	5.60	26.40	8.323
Al	4	11.743	8.38	13.39	1.973
Cd	2	0.005	0.01	0.01	0.001

TABLE A-34. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 437 - 140 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	279.835	49.00	1,340.00	309.148
TKN	34	59.229	14.00	204.40	36.197
$N\text{-}NH_4$	33	35.200	0.00	114.80	24.550
$N\text{-}NO_3$	38	242.283	11.00	545.00	159.202
$N\text{-}NO_2$	36	11.513	0.12	42.40	11.627
BOD_5	2	84.000	41.00	127.00	43.000
COD	33	178.697	48.00	602.00	121.462
TP	35	3.357	0.80	9.90	2.461
Cl^-	35	189.494	102.30	240.80	27.251
pH	40	7.467	6.60	7.70	0.278
K	5	117.836	41.12	228.73	67.778
Na	5	318.466	165.38	529.20	120.485
Ca	5	353.600	245.00	450.00	90.210
Mg	5	83.420	39.30	130.00	37.686
Cu	4	0.635	0.28	1.44	0.470
Zn	4	0.658	0.31	0.85	0.207
Fe	4	13.475	2.90	34.60	12.476
Al	4	4.413	3.15	6.85	1.455
Cd	4	0.003	0.00	0.01	0.002

TABLE A-35. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 446 - 160 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	460.363	38.00	5,520.00	935.936
TKN	36	59.400	11.20	283.00	45.401
$N-NH_4$	35	27.574	0.00	98.00	25.144
$N-NO_3$	36	157.486	32.50	412.50	101.641
$N-NO_2$	35	7.197	0.20	48.80	10.527
BOD_5	2	34.500	4.00	65.00	30.500
COD	36	173.556	61.00	763.00	132.582
TP	33	5.977	0.70	63.00	10.947
Cl^-	34	167.179	60.50	214.20	30.523
pH	41	7.429	6.80	8.10	0.312
K	6	111.245	33.41	203.00	53.440
Na	6	275.545	169.63	434.70	84.809
Ca	6	418.917	300.60	545.00	82.641
Mg	6	74.383	51.50	94.50	16.088
Cu	6	0.295	0.23	0.35	0.039
Zn	6	0.643	0.30	1.27	0.323
Fe	6	28.733	6.90	58.00	17.059
Al	6	8.413	6.10	10.35	1.587
Cd	5	0.003	0.00	0.01	0.002

TABLE A-36. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 447 - 160 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/79 to 12/31/79

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	35	514.829	5.00	9,664.00	1,601.057
TKN	36	48.683	8.00	103.60	18.991
$N\text{-}NH_4$	35	25.234	0.00	61.60	19.523
$N\text{-}NO_3$	39	232.673	15.00	522.50	160.245
$N\text{-}NO_2$	37	14.629	0.12	63.60	13.976
BOD_5	2	157.500	152.00	163.00	5.500
COD	34	148.559	62.00	344.00	65.138
TP	35	2.959	0.60	21.00	3.333
Cl^-	35	188.657	93.00	243.10	33.525
pH	36	7.400	6.70	8.10	0.254
K	6	178.508	35.98	334.10	102.215
Na	6	307.758	193.73	449.82	77.174
Ca	6	420.333	288.00	565.00	100.994
Mg	6	87.883	42.30	134.50	36.515
Cu	6	0.328	0.21	0.42	0.074
Zn	6	0.745	0.36	1.39	0.407
Fe	6	11.817	4.00	22.30	5.637
Al	6	7.980	4.03	16.20	4.063
Cd	5	0.005	0.00	0.01	0.003

TABLE A-37. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 518 - 30 cm Depth, Eight Points in BLWRS - 12
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	16	402.438	14.00	714.00	220.499
TKN	18	251.000	75.60	431.20	120.669
$N\text{-}NH_4$	16	154.988	30.80	349.00	101.662
$N\text{-}NO_3$	18	128.786	12.30	430.00	108.662
$N\text{-}NO_2$	17	14.367	0.21	67.20	18.301
$P\text{-}PO_4$	9	29.100	8.00	45.60	14.429
C org	10	395.000	144.00	937.50	255.445
BOD_5	2	129.500	84.00	175.00	45.500
COD	18	961.722	246.00	2,390.00	642.599
TP	15	34.313	8.40	65.00	18.292
Cl^-	18	117.183	26.80	280.20	71.197
pH	15	7.173	6.10	8.00	0.437
K	8	216.813	147.00	345.00	59.310
Na	8	88.825	38.50	132.50	30.979
Ca	8	255.412	100.00	465.00	121.022
Mg	8	71.788	43.50	122.50	23.727
Cu	9	0.238	0.16	0.35	0.062
Zn	8	1.660	0.80	3.55	0.823
Fe	9	5.467	3.30	8.00	1.486
Al	9	6.278	1.30	18.80	6.055

TABLE A-38. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 528 - 80 cm Depth, Eight Points in BLWRS - 12
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	30	167.700	32.00	566.00	107.285
TKN	32	118.584	44.80	260.40	51.708
$N\text{-}NH_4$	31	99.361	39.20	221.80	43.659
$N\text{-}NO_3^-$	33	187.858	37.50	535.00	115.180
$N\text{-}NO_2^-$	32	36.340	0.26	288.00	62.477
$P\text{-}PO_4$	20	18.130	5.50	47.00	8.302
C org	22	142.773	54.00	334.00	68.009
BOD_5	5	57.500	13.00	143.00	44.797
COD	32	497.875	149.00	1,534.00	317.653
TP	30	22.030	8.80	47.50	7.906
Cl^-	33	123.376	80.90	208.60	30.999
pH	22	7.023	6.40	7.50	0.312
K	14	253.357	150.00	350.00	55.408
Na	14	78.000	40.00	173.00	34.367
Ca	14	423.357	225.00	876.00	161.606
Mg	14	54.429	30.00	89.50	15.251
Cu	14	0.270	0.10	0.56	0.127
Zn	14	0.564	0.00	1.30	0.371
Fe	11	3.764	1.60	6.70	1.726
Al	14	4.971	1.40	12.60	3.471

TABLE A-39. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 618 - 30 cm Depth, Eigth Points in BLWRS - 34
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	15	872.333	21.00	2,880.00	1,097.649
TKN	17	367.000	168.00	716.80	137.348
$N\text{-}NH_4$	16	231.700	0.00	630.00	150.633
$N\text{-}NO_3$	17	57.282	5.60	176.00	48.019
$N\text{-}NO_2$	16	5.106	0.64	24.00	6.689
$P\text{-}PO_4$	9	87.989	22.00	200.00	64.991
C org	12	416.958	194.00	1,020.00	221.087
BOD_5	2	217.500	175.00	260.00	42.500
COD	17	1,331.706	304.00	3,809.00	904.346
TP	14	88.636	30.00	205.00	50.503
Cl^-	17	204.476	109.10	821.90	159.498
pH	10	7.360	7.10	8.10	0.353
K	11	291.455	70.00	517.50	107.932
Na	11	82.555	43.50	129.00	24.057
Ca	11	193.345	80.00	435.00	99.645
Mg	11	67.645	48.00	108.00	15.231
Cu	10	0.408	0.17	0.75	0.158
Zn	11	1.775	0.95	4.25	1.041
Fe	10	10.820	4.60	24.70	6.036
Al	11	3.325	0.30	7.38	1.936

TABLE A-40. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 628 - 80 cm Depth, Eight Points in BLWRS - 34
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	26	551.846	57.00	2,340.00	606.784
TKN	27	210.504	28.00	498.40	152.954
$N\text{-}NH_4$	27	137.789	0.00	435.80	120.964
$N\text{-}NO_3$	28	172.525	56.00	493.00	103.153
$N\text{-}NO_2$	27	21.356	0.49	288.00	54.250
$P\text{-}PO_4$	17	19.759	7.50	60.00	13.479
C org	19	439.289	67.00	3,176.00	682.345
BOD_5	4	106.750	36.00	251.00	34.727
COD	28	1,106.964	106.00	3,854.00	975.982
TP	26	37.531	4.40	153.00	32.087
Cl^-	28	149.957	100.00	275.00	36.901
pH	17	7.294	6.00	8.20	0.461
K	12	243.792	150.00	457.50	82.646
Na	12	95.625	65.50	146.30	26.743
Ca	12	245.000	90.00	545.00	133.804
Mg	12	150.625	99.00	213.60	32.170
Cu	11	0.273	0.09	0.80	0.181
Zn	12	0.925	0.05	2.05	0.698
Fe	11	4.982	2.10	9.30	2.052
Al	12	3.324	0.50	10.00	2.339

TABLE A-41. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 136 - 140 cm Depth, Two Points in BLWRS - 1 Time Period - 01/01/80 to 12/31/80					
Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	29	69.103	14.00	405.00	84.194
TKN	32	132.700	44.80	470.40	83.658
$N-NH_4$	31	94.639	7.00	243.60	49.974
$N-NO_3$	32	166.091	5.60	500.00	115.788
$N-NO_2$	30	33.251	0.10	236.00	57.872
$P-PO_4$	16	2.156	0.50	9.00	2.067
C org	18	160.139	37.00	740.00	166.237
BOD_5	5	22.700	5.00	35.00	9.958
COD	32	259.438	25.00	1,182.00	222.059
TP	29	2.226	0.30	13.00	2.335
Cl^-	32	135.381	72.10	213.00	28.890
pH	23	7.078	6.00	8.10	0.441
K	13	228.923	145.00	375.00	73.377
Na	13	86.862	53.00	116.00	17.366
Ca	13	359.946	145.00	480.00	102.249
Mg	13	55.369	20.00	77.50	13.539
Cu	13	0.230	0.07	0.57	0.149
Zn	14	0.571	0.05	1.85	0.476
Fe	13	7.992	2.30	22.30	5.938
Al	13	5.124	1.32	13.00	3.720

TABLE A-42. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 137 - 140 cm Depth, Two Points in BLWRS - 1
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	86.806	16.00	410.00	89.015
TKN	33	73.958	14.00	313.60	56.936
$N-NH_4$	32	49.431	0.00	163.80	32.901
$N-NO_3$	32	294.331	101.20	750.00	130.347
$N-NO_2$	31	18.792	0.90	56.50	14.756
$P-PO_4$	17	5.718	0.50	19.50	4.723
C org	19	124.842	70.00	300.00	54.431
BOD_5	5	33.000	9.00	80.00	27.275
COD	33	294.970	60.00	1,027.00	224.986
TP	29	6.445	1.00	45.00	8.898
Cl^-	33	145.527	75.90	245.20	41.253
pH	22	6.959	6.10	8.00	0.413
K	15	215.600	122.50	344.50	66.980
Na	15	84.787	45.00	129.00	23.918
Ca	15	506.500	362.50	745.00	115.768
Mg	15	55.380	43.50	68.00	6.907
Cu	16	0.261	0.09	0.46	0.103
Zn	15	0.590	0.00	1.70	0.425
Fe	14	5.000	0.60	11.00	2.507
Al	15	9.721	3.50	20.90	4.853

TABLE A-43. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 146 - 160 cm Depth, Two Locations in BLWRS - 1
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	78.412	13.00	262.00	48.217
TKN	36	135.261	58.80	282.80	52.452
$N-NH_4$	34	99.129	14.80	196.00	41.422
$N-NO_3$	36	157.236	5.50	525.00	135.913
$N-NO_2$	34	26.621	0.20	228.00	55.057
$P-PO_4$	20	2.315	0.40	4.90	1.222
C org	22	105.568	46.50	280.00	59.155
BOD_5	5	27.800	7.00	45.00	12.258
COD	36	256.917	72.00	1,239.00	234.936
TP	33	2.627	0.70	7.50	1.535
Cl^-	36	141.206	78.00	196.10	27.864
pH	21	6.971	6.20	7.90	0.373
K	16	207.375	65.00	305.00	57.652
Na	16	88.375	55.50	135.50	28.712
Ca	16	350.938	125.50	625.00	139.930
Mg	16	64.850	26.00	93.00	16.198
Cu	16	0.236	0.06	0.38	0.088
Zn	15	0.577	0.00	1.90	0.474
Fe	15	7.647	2.10	42.50	9.573
Al	16	6.671	0.78	27.50	6.787

TABLE A-44. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 147 - 160 cm Depth, Two Locations in BLWRS - 1
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	63.118	10.00	329.00	58.538
TKN	36	79.956	19.60	210.00	39.764
$N-NH_4$	35	56.580	8.40	112.00	24.121
$N-NO_3$	36	307.392	50.00	1,020.00	179.742
$N-NO_2$	34	9.675	0.97	26.40	7.648
$P-PO_4$	20	1.935	0.40	5.30	1.177
C org	21	85.905	50.00	229.00	38.535
BOD_5	5	16.200	4.00	27.50	8.262
COD	36	203.058	59.00	504.00	91.060
TP	33	2.786	0.40	22.50	3.778
Cl^-	36	155.875	101.90	247.50	35.259
pH	22	6.850	6.30	7.40	0.304
K	16	201.469	100.00	300.00	67.374
Na	16	87.831	40.00	128.50	25.269
Ca	16	513.719	228.50	852.50	142.094
Mg	16	63.669	43.50	82.80	10.755
Cu	15	0.282	0.08	0.57	0.118
Zn	16	0.534	0.00	1.45	0.394
Fe	16	4.562	0.10	8.50	1.988
Al	16	11.496	0.77	21.80	5.989

TABLE A-45. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 236 - 140 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	284.906	44.00	1,286.00	239.300
TKN	34	504.888	260.40	739.20	121.355
$N-NH_4$	33	423.903	39.40	725.20	167.576
$N-NO_3$	34	13.565	1.20	190.00	31.646
$N-NO_2$	32	1.006	0.09	11.60	2.042
$P-PO_4$	16	40.200	14.00	83.00	17.679
C org	19	330.447	50.00	690.00	156.309
BOD_5	5	68.800	5.00	111.00	38.859
COD	34	794.647	120.00	1,794.00	428.337
TP	31	36.874	9.10	83.50	23.729
Cl^-	34	153.435	73.40	249.80	30.944
pH	24	7.121	6.60	7.60	0.286
K	16	280.938	200.00	370.00	50.073
Na	16	75.894	50.00	107.50	20.018
Ca	16	158.969	85.00	330.00	56.305
Mg	16	46.150	28.50	71.30	11.831
Cu	15	0.197	0.03	0.35	0.099
Zn	16	0.700	0.05	1.65	0.456
Fe	15	10.967	2.60	31.00	7.553
Al	15	2.574	1.10	8.10	1.794

TABLE A-46. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 237 - 140 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	111.824	14.00	580.00	134.567
TKN	36	177.189	19.60	655.20	139.072
$N\text{-}NH_4$	35	149.469	19.60	543.20	110.211
$N\text{-}NO_3$	36	127.447	3.00	1,190.00	195.258
$N\text{-}NO_2$	34	8.079	0.38	52.80	13.064
$P\text{-}PO_4$	17	3.585	0.70	32.00	7.139
C org	21	135.762	55.00	326.50	70.428
BOD_5	4	38.250	10.00	86.00	28.604
COD	35	541.566	146.00	3,386.00	618.889
TP	33	6.573	0.90	56.50	10.073
Cl^-	36	146.969	68.40	240.80	36.871
pH	25	6.928	6.20	7.40	0.327
K	16	216.531	115.00	325.00	59.915
Na	16	79.206	53.30	114.50	20.347
Ca	16	315.344	210.00	445.00	57.201
Mg	16	51.256	34.80	75.50	10.791
Cu	16	0.274	0.10	0.52	0.113
Zn	16	0.459	0.00	1.00	0.291
Fe	15	9.713	0.00	47.30	13.093
Al	16	4.020	0.69	12.20	3.136

TABLE A-47. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 246 - 160 cm Depth, Two Locations in BLWRS - 2
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	386.188	26.00	1,336.00	275.147
TKN	34	455.741	39.20	725.20	172.475
$N\text{-}NH_4$	33	389.058	0.00	686.00	187.824
$N\text{-}NO_3$	34	33.909	2.00	500.00	83.038
$N\text{-}NO_2$	32	0.874	0.18	2.90	0.578
$P\text{-}PO_4$	17	27.066	4.90	45.00	10.253
C org	20	307.500	112.00	550.00	105.472
BOD_5	5	130.200	45.00	268.00	73.904
COD	34	965.500	216.00	2,431.00	548.531
TP	31	25.035	1.40	66.00	14.812
Cl^-	34	157.800	118.20	261.50	30.305
pH	24	7.125	6.70	7.50	0.218
K	16	290.281	195.00	425.00	62.854
Na	16	78.775	47.50	115.00	19.446
Ca	16	183.081	70.00	305.00	68.722
Mg	16	48.938	31.30	74.30	10.726
Cu	15	0.237	0.09	0.60	0.133
Zn	16	0.828	0.00	2.70	0.572
Fe	15	15.233	2.50	51.70	13.937
Al	16	4.269	0.18	11.32	3.437

TABLE A-48. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 247 - 160 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	34	151.029	10.00	660.00	149.188
TKN	36	159.533	56.00	313.60	64.936
$N\text{-}NH_4$	35	129.057	23.80	232.40	57.111
$N\text{-}NO_3$	36	131.781	2.00	850.00	160.710
$N\text{-}NO_2$	34	8.141	0.14	42.40	13.988
$P\text{-}PO_4$	18	3.858	1.30	12.00	3.005
C org	21	239.524	65.00	1,191.00	272.522
BOD_5	5	62.700	15.00	192.00	65.634
COD	35	594.649	69.00	2,261.00	591.874
TP	33	4.015	0.60	16.00	3.352
Cl^-	36	160.086	115.70	213.00	26.920
pH	23	6.861	6.30	7.30	0.293
K	16	177.188	45.00	360.00	86.643
Na	16	93.269	60.00	160.50	30.330
Ca	16	358.488	135.00	622.50	109.392
Mg	16	66.463	44.00	91.50	12.159
Cu	16	0.304	0.08	0.88	0.223
Zn	16	0.466	0.10	0.85	0.207
Fe	16	15.588	0.60	82.60	19.478
Al	16	4.778	0.42	15.50	4.475

TABLE A-49. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 336 - 140 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	208.484	40.00	736.00	143.803
TKN	33	354.509	168.00	515.20	92.141
$N\text{-}NH_4$	32	313.563	42.00	512.40	97.857
$N\text{-}NO_3$	33	42.009	1.25	245.00	50.894
$N\text{-}NO_2$	31	57.657	0.10	1,056.00	198.122
$P\text{-}PO_4$	17	22.547	8.70	40.00	8.958
C_{org}	18	273.639	155.00	444.00	92.581
BOD_5	5	72.000	60.00	81.00	8.883
COD	32	796.156	369.00	2,015.00	356.998
TP	30	20.850	6.00	42.00	10.574
Cl^-	33	142.306	91.70	217.60	32.997
pH	23	7.239	6.60	8.00	0.320
K	15	264.333	175.00	394.00	58.582
Na	15	89.180	40.00	152.80	30.866
Ca	15	190.467	80.00	305.00	81.269
Mg	15	85.520	40.00	150.00	32.278
Cu	14	0.263	0.06	0.55	0.137
Zn	15	0.377	0.00	0.65	0.203
Fe	14	10.279	0.20	36.60	11.357
Al	12	2.352	0.58	5.10	1.315
Cd	1	0.920	0.92	0.92	0.000

TABLE A-50. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 337 - 140 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	113.344	20.00	340.00	73.218
TKN	34	116.571	16.80	354.80	73.318
$N\text{-}NH_4$	33	95.897	12.10	312.50	68.076
$N\text{-}NO_3$	34	181.679	12.50	505.00	104.932
$N\text{-}NO_2$	32	20.009	0.10	108.80	30.126
$P\text{-}PO_4$	18	9.456	2.10	40.60	10.969
C org	19	187.763	75.00	816.00	159.626
BOD_5	5	34.400	15.00	59.00	15.121
COD	34	390.032	61.00	1,741.00	360.394
TP	31	8.842	1.20	46.60	9.615
Cl^-	34	153.506	89.30	219.50	32.093
pH	24	7.083	6.40	7.90	0.368
K	15	160.933	45.00	275.00	70.008
Na	15	100.087	35.00	155.50	35.761
Ca	15	246.353	80.00	477.50	102.660
Mg	15	146.120	37.50	244.00	48.852
Cu	15	0.298	0.05	0.78	0.162
Zn	15	0.720	0.15	2.00	0.405
Fe	15	9.453	2.10	54.40	12.697
Al	13	3.472	1.17	8.60	2.069

TABLE A-51. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 346 - 160 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	28	279.964	28.00	648.00	160.289
TKN	31	442.716	126.00	728.00	140.515
$N\text{-}NH_4$	30	304.513	19.60	686.00	157.935
$N\text{-}NO_3$	31	87.623	6.00	420.00	103.679
$N\text{-}NO_2$	29	20.556	0.35	118.40	33.177
$P\text{-}PO_4$	15	14.360	2.00	43.00	10.374
C org	16	289.969	140.00	720.00	139.434
BOD_5	5	84.000	7.00	301.00	110.591
COD	31	809.774	312.00	1,482.00	402.539
TP	28	18.473	1.70	54.00	12.910
Cl^-	30	187.937	55.60	444.50	95.906
pH	23	7.309	6.70	7.90	0.316
K	13	285.269	135.00	432.00	91.275
Na	13	112.738	42.80	223.00	53.505
Ca	14	270.129	122.00	500.00	99.571
Mg	13	148.654	70.50	257.50	45.229
Cu	14	0.261	0.09	0.84	0.191
Zn	14	1.514	0.41	6.00	1.448
Fe	14	14.229	0.20	51.20	12.469
Al	13	9.175	1.32	50.00	12.059

TABLE A-52. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 347 - 160 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	32	154.688	21.00	506.00	128.471
TKN	34	98.400	14.00	263.20	71.856
$N\text{-}NH_4$	32	73.141	8.40	234.40	60.110
$N\text{-}NO_3$	34	297.159	20.00	696.00	140.052
$N\text{-}NO_2$	32	34.252	0.39	313.60	63.601
$P\text{-}PO_4$	19	7.016	2.20	18.60	4.026
C org	19	133.921	55.00	220.00	39.388
BOD_5	5	25.600	4.00	43.00	13.336
COD	34	330.797	78.00	1,128.00	245.624
TP	31	7.094	1.50	20.50	4.331
Cl^-	34	165.294	83.30	354.90	43.701
pH	24	7.067	6.30	7.80	0.368
K	15	178.800	50.00	390.00	94.601
Na	15	126.973	75.00	189.00	31.974
Ca	15	334.533	120.00	427.50	87.220
Mg	15	196.287	76.00	510.00	96.664
Cu	14	0.304	0.14	0.66	0.133
Zn	15	0.941	0.00	5.40	1.279
Fe	15	5.753	1.30	12.40	3.017
Al	15	6.499	1.29	12.20	3.591

TABLE A-53. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 436 - 140 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	91.355	5.00	297.00	72.711
TKN	34	85.153	30.80	411.60	70.982
$N\text{-}NH_4$	32	70.144	18.20	390.60	70.823
$N\text{-}NO_3$	33	197.658	6.30	467.50	139.967
$N\text{-}NO_2$	31	20.665	0.39	118.40	29.018
$P\text{-}PO_4$	17	2.829	0.70	8.20	1.870
C org	20	111.475	26.00	447.50	89.936
BOD_5	5	14.300	4.00	42.50	14.260
COD	34	239.868	28.00	924.00	178.789
TP	30	2.843	0.90	9.00	2.099
Cl^-	34	159.341	90.40	282.50	38.318
pH	24	7.008	6.00	7.80	0.394
K	15	173.800	80.00	345.00	75.226
Na	15	98.493	56.50	171.30	35.113
Ca	15	285.367	130.00	462.50	108.517
Mg	15	152.187	108.00	247.50	35.248
Cu	13	0.204	0.10	0.36	0.084
Zn	15	0.497	0.00	1.10	0.334
Fe	14	7.564	1.70	18.50	5.769
Al	14	4.600	0.28	9.20	2.773

TABLE A-54. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 437 - 140 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	31	87.774	2.00	405.00	84.991
TKN	33	102.921	8.40	495.60	98.197
$N\text{-}NH_4$	32	65.119	7.00	420.00	75.021
$N\text{-}NO_3$	33	261.973	10.00	545.00	155.642
$N\text{-}NO_2$	31	14.532	0.44	118.40	24.039
$P\text{-}PO_4$	18	3.872	1.00	8.50	2.123
C org	19	110.263	24.50	295.00	74.446
BOD_5	5	33.800	10.00	70.00	19.853
COD	33	306.758	78.00	1,098.00	*
TP	30	4.863	0.50	24.00	4.339
Cl^-	33	146.491	90.90	226.40	35.164
pH	24	7.171	6.70	7.70	0.303
K	15	209.167	90.00	370.00	72.908
Na	15	108.873	47.50	219.50	38.990
Ca	15	255.100	120.00	505.00	91.389
Mg	15	168.673	96.00	305.00	50.170
Cu	13	0.353	0.14	1.13	0.265
Zn	15	0.720	0.00	1.75	0.488
Fe	14	9.429	1.00	65.00	15.830
Al	13	5.105	0.84	12.00	3.425

*data missing

TABLE A-55. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 446 - 160 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	30	70.867	25.00	127.00	31.577
TKN	32	70.463	16.80	151.20	30.574
$N\text{-}NH_4$	29	57.166	16.80	151.20	30.558
$N\text{-}NO_3$	32	239.488	4.50	587.50	142.188
$N\text{-}NO_2$	29	16.573	0.70	124.80	25.312
$P\text{-}PO_4$	16	3.838	0.70	11.00	2.851
C org	17	73.824	20.00	191.50	40.193
BOD_5	5	16.600	1.00	44.00	18.059
COD	31	215.745	51.00	689.00	137.881
TP	29	4.124	0.40	12.30	3.031
Cl^-	32	147.519	77.30	231.80	35.493
pH	25	7.080	6.10	7.90	0.460
K	15	150.667	60.00	340.00	73.303
Na	15	101.387	60.50	148.50	30.238
Ca	14	294.821	175.00	405.00	63.944
Mg	15	134.933	68.00	196.50	29.381
Cu	13	0.277	0.09	0.75	0.163
Zn	14	0.550	0.05	1.20	0.372
Fe	14	6.836	1.70	20.30	5.069
Al	14	5.445	1.80	11.90	2.626

TABLE A-56. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 447 - 160 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/80 to 12/31/80

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	33	87.000	18.00	280.00	60.109
TKN	35	122.994	18.00	966.00	154.592
$N\text{-}NH_4$	34	84.624	8.40	315.00	65.825
$N\text{-}NO_3$	35	193.509	20.00	497.50	129.213
$N\text{-}NO_2$	33	23.730	0.20	208.00	49.283
$P\text{-}PO_4$	19	3.653	0.40	10.20	2.636
C org	20	108.050	56.50	255.00	43.497
BOD_5	4	60.875	17.00	82.50	25.730
COD	35	270.714	43.00	958.00	222.020
TP	32	3.875	0.80	11.30	2.406
Cl^-	35	166.906	90.90	224.60	33.090
pH	24	7.079	6.50	7.70	0.354
K	15	214.067	85.00	385.00	93.344
Na	15	114.073	52.00	171.30	35.023
Ca	15	270.733	134.00	570.00	134.558
Mg	15	181.453	120.80	280.00	42.851
Cu	11	0.340	0.10	1.12	0.269
Zn	15	0.500	0.00	1.75	0.428
Fe	14	5.150	2.10	9.20	2.158
Al	13	4.394	0.54	16.90	5.209

TABLE A-57. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 528 - 30 cm Depth, Eight Points in BLWRS - 2
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	1	618.000	618.00	618.00	0.000
TKN	1	131.600	131.60	131.60	0.000
$N-NH_4$	1	126.000	126.00	126.00	0.000
$N-NO_3$	1	75.000	75.00	75.00	0.000
$N-NO_2$	1	0.000	0.00	0.00	0.000
$P-PO_4$	1	11.500	11.50	11.50	0.000
C org	1	360.000	360.00	360.00	0.000
COD	1	782.000	782.00	782.00	0.000
TP	1	15.000	15.00	15.00	0.000
Cl^-	1	111.600	111.60	111.60	0.000
K	1	285.500	285.50	285.50	0.000
Na	1	39.500	39.50	39.50	0.000
Ca	1	225.000	225.00	225.00	0.000
Mg	1	55.500	55.50	55.50	0.000
Cu	1	0.100	0.10	0.10	0.000
Zn	1	0.200	0.20	0.20	0.000
Fe	1	3.020	3.02	3.02	0.000
Al	1	1.670	1.67	1.67	0.000

TABLE A-58. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 146 - 160 cm Depth, Two Points in BLWRS - I
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	1	200.000	200.00	200.00	0.000
TKN	1	44.800	44.80	44.80	0.000
$N\text{-}NH_4$	1	33.600	33.60	33.60	0.000
$N\text{-}NO_3$	1	100.000	100.00	100.00	0.000
$N\text{-}NO_2$	1	14.400	14.40	14.40	0.000
$P\text{-}PO_4$	1	2.400	2.40	2.40	0.000
C org	1	145.000	145.00	145.00	0.000
COD	1	194.000	194.00	194.00	0.000
TP	1	2.600	2.60	2.60	0.000
Cl^-	1	103.600	103.60	103.60	0.000

TABLE A-59. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 147 - 160 cm Depth, Two Points in BLWRS - 1
Time Period - 01/01/81/ to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	3	274.000	216.00	372.00	69.685
TKN	3	101.733	53.20	140.00	36.172
$N-NH_4$	3	88.667	44.80	114.80	31.207
$N-NO_3$	3	34.000	13.00	72.00	26.920
$N-NO_2$	3	5.067	3.20	7.80	1.975
$P-PO_4$	3	6.300	4.20	8.00	1.577
C org	2	178.000	86.00	270.00	92.000
COD	3	321.000	271.00	399.00	55.881
TP	3	12.600	7.00	22.00	6.687
Cl^-	3	95.900	84.10	108.10	9.802
pH	2	7.950	7.40	8.50	0.550
K	1	237.000	237.00	237.00	0.000
Na	1	61.500	61.50	61.50	0.000
Ca	1	250.000	250.00	250.00	0.000
Mg	1	48.000	48.00	48.00	0.000
Cu	1	0.180	0.18	0.18	0.000
Zn	1	0.250	0.25	0.25	0.000
Fe	1	5.340	5.34	5.34	0.000
Al	1	2.860	2.86	2.86	0.000

TABLE A-60. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 236 - 140 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	2	284.000	218.00	350.00	66.000
TKN	2	596.400	523.60	669.20	72.800
$N\text{-}NH_4$	2	569.800	518.00	621.60	51.800
$N\text{-}NO_3$	2	17.600	7.20	28.00	10.400
$N\text{-}NO_2$	2	0.350	0.30	0.40	0.050
$P\text{-}PO_4$	2	4.850	3.50	6.20	1.350
C org	2	382.500	297.50	467.50	85.000
COD	2	384.000	373.00	395.00	11.000
TP	2	6.050	3.70	8.40	2.350
Cl^-	2	132.300	125.00	139.60	7.300
pH	1	7.600	7.60	7.60	0.000
K	1	299.000	299.00	299.00	0.000
Na	1	64.000	64.00	64.00	0.000
Ca	1	35.000	35.00	35.00	0.000
Mg	1	46.500	46.50	46.50	0.000
Cu	1	0.090	0.09	0.09	0.000
Zn	1	0.100	0.10	0.10	0.000
Fe	1	7.450	7.45	7.45	0.000
Al	1	2.570	2.57	2.57	0.000

TABLE A-61. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 237 - 140 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	4	255.500	210.00	300.00	37.480
TKN	4	187.600	154.00	229.60	28.486
$N\text{-}NH_4$	4	158.900	120.40	207.20	35.823
$N\text{-}NO_3$	4	21.000	3.00	45.00	15.937
$N\text{-}NO_2$	4	0.975	0.10	3.40	1.401
$P\text{-}PO_4$	4	4.300	2.70	6.00	1.465
C org	3	379.167	155.00	505.00	158.907
COD	4	836.750	746.00	880.00	53.513
TP	4	7.625	3.60	11.00	2.637
Cl^-	4	93.875	73.70	108.10	13.209
pH	3	7.467	7.20	7.90	0.309
K	2	247.750	230.00	265.50	17.750
Na	2	49.250	49.00	49.50	0.250
Ca	2	122.500	40.00	205.00	82.500
Mg	2	67.250	57.50	77.00	9.750
Cu	2	0.135	0.09	0.18	0.045
Zn	2	0.125	0.10	0.15	0.025
Fe	2	28.495	17.09	39.90	11.405
Al	2	1.400	1.30	1.50	0.100

TABLE A-62. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 246 - 160 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	2	456.000	266.00	646.00	190.000
TKN	2	652.400	560.00	744.80	92.400
$N-NH_4$	2	600.600	520.80	680.40	79.800
$N-NO_3$	2	42.500	25.00	60.00	17.500
$N-NO_2$	2	0.550	0.30	0.80	0.250
$P-PO_4$	2	16.750	11.00	22.50	5.750
C org	2	337.500	232.50	442.50	105.000
COD	2	432.000	405.00	459.00	27.000
TP	2	20.450	11.70	29.20	8.750
Cl^-	2	124.500	109.40	139.60	15.100
pH	1	7.400	7.40	7.40	0.000
K	1	323.000	323.00	323.00	0.000
Na	1	55.000	55.00	55.00	0.000
Ca	1	50.000	50.00	50.00	0.000
Mg	1	45.000	45.00	45.00	0.000
Cu	1	0.090	0.09	0.09	0.000
Zn	1	0.600	0.60	0.60	0.000
Fe	1	8.590	8.59	8.59	0.000
Al	1	4.720	4.72	4.72	0.000

TABLE A-63. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 247 - 160 cm Depth, Two Points in BLWRS - 2
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	4	396.000	328.00	566.00	98.519
TKN	4	201.600	123.20	322.00	73.683
$N-NH_4$	4	175.700	98.00	296.80	73.666
$N-NO_3$	4	156.875	25.00	290.00	114.774
$N-NO_2$	4	3.075	0.50	6.70	2.448
$P-PO_4$	4	3.350	2.30	4.50	0.792
C org	3	496.667	425.00	640.00	101.352
COD	4	648.750	130.00	1,565.00	544.901
TP	4	4.275	3.00	7.20	1.708
Cl^-	4	107.575	73.70	126.10	20.087
pH	2	7.750	7.60	7.90	0.150
K	2	252.750	252.00	253.50	0.750
Na	2	56.500	54.00	59.00	2.500
Ca	2	137.500	70.00	205.00	67.500
Mg	2	68.750	63.50	74.00	5.250
Cu	2	0.085	0.06	0.11	0.025
Zn	2	0.175	0.15	0.20	0.025
Fe	2	47.700	41.30	54.10	6.400
Al	2	1.835	1.80	1.87	0.035

TABLE A-64. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 336 - 140 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	3	546.667	420.00	708.00	120.104
TKN	3	368.667	257.60	448.00	80.904
$N\text{-}NH_4$	3	332.267	221.20	389.20	78.544
$N\text{-}NO_3^-$	3	56.333	9.00	125.00	49.701
$N\text{-}NO_2^-$	3	2.400	0.50	4.10	1.476
$P\text{-}PO_4$	3	5.967	1.00	12.50	4.824
C org	2	521.250	387.50	655.00	133.750
COD	3	715.000	221.00	1,281.00	435.728
TP	3	7.167	2.40	14.60	5.326
Cl^-	3	111.033	79.50	144.20	26.439
pH	2	8.050	7.70	8.40	0.350
K	2	171.500	106.00	237.00	65.500
Na	2	36.250	17.50	55.00	18.750
Ca	2	95.000	60.00	130.00	35.000
Mg	2	58.750	51.50	66.00	7.250
Cu	2	0.155	0.14	0.17	0.015
Zn	2	0.275	0.25	0.30	0.025
Fe	2	22.935	9.43	36.44	13.505
Al	2	2.060	1.00	3.12	1.060

TABLE A-65. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 337 - 140 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	4	206.000	40.00	322.00	102.849
TKN	4	167.300	100.80	266.00	70.290
$N-NH_4$	4	146.300	70.00	243.60	67.006
$N-NO_3$	4	60.750	15.00	94.00	31.043
$N-NO_2$	4	7.800	0.60	16.40	6.924
$P-PO_4$	4	4.750	2.70	6.50	1.440
C org	2	342.500	305.00	380.00	37.500
COD	4	532.500	177.00	1,004.00	324.261
TP	4	6.200	4.50	7.40	1.056
Cl^-	4	117.400	93.50	131.80	15.860
pH	2	7.850	7.60	8.10	0.250
K	2	202.500	137.50	267.50	65.000
Na	2	62.000	60.50	63.50	1.500
Ca	2	77.500	30.00	125.00	47.500
Mg	2	177.500	150.00	205.00	27.500
Cu	2	0.125	0.10	0.15	0.025
Zn	2	0.250	0.25	0.25	0.000
Fe	2	28.665	17.83	39.50	10.835
Al	2	1.575	1.15	2.00	0.425

TABLE A-66. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 346 - 160 cm Depth in BLWRS - 3
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
pH	1	7.800	7.80	7.80	0.000

TABLE A-67. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 347 - 160 cm Depth, Two Points in BLWRS - 3
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	1	212.000	212.00	212.00	0.000
TKN	1	112.000	112.00	112.00	0.000
$N\text{-}NH_4$	1	100.800	100.80	100.80	0.000
$N\text{-}NO_3$	1	100.000	100.00	100.00	0.000
$N\text{-}NO_2$	1	7.600	7.60	7.60	0.000
$P\text{-}PO_4$	1	9.500	9.50	9.50	0.000
C org	1	320.000	320.00	320.00	0.000
COD	1	337.000	337.00	337.00	0.000
TP	1	9.600	9.60	9.60	0.000
Cl^-	1	120.600	120.60	120.60	0.000
pH	1	7.700	7.70	7.70	0.000
K	1	180.000	180.00	180.00	0.000
Na	1	63.500	63.50	63.50	0.000
Ca	1	165.000	165.00	165.00	0.000
Mg	1	218.500	218.50	218.00	0.000
Cu	1	0.130	0.13	0.13	0.000
Zn	1	0.500	0.50	0.50	0.000
Fe	1	13.900	13.90	13.90	0.000
Al	1	0.000	0.00	0.00	0.000

TABLE A-68. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 436 - 140 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	4	84.750	50.00	134.00	33.833
TKN	4	210.000	70.00	534.80	190.276
$N\text{-}NH_4$	4	98.000	64.40	140.00	31.863
$N\text{-}NO_3$	4	314.000	70.00	525.00	166.405
$N\text{-}NO_2$	4	4.275	2.20	6.20	1.452
$P\text{-}PO_4$	4	2.550	0.40	3.40	1.252
C org	2	54.500	18.00	91.00	36.500
COD	4	99.500	23.00	154.00	49.561
TP	4	3.675	1.70	6.20	1.628
Cl^-	4	131.825	116.10	148.70	13.407
pH	3	7.500	7.00	8.00	0.408
K	2	173.250	161.00	185.50	12.250
Na	2	91.750	79.50	104.00	12.250
Ca	2	192.500	170.00	215.00	22.500
Mg	2	193.750	190.00	197.50	3.750
Cu	2	0.085	0.04	0.13	0.045
Zn	2	0.100	0.10	0.10	0.000
Fe	2	3.960	2.14	5.78	1.820
Al	2	6.470	2.70	10.24	3.770

TABLE A-69. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 437 - 140 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	2	136.000	118.00	154.00	18.000
TKN	2	61.600	30.80	92.40	30.800
$N\text{-}NH_4$	2	58.800	30.80	86.80	28.000
$N\text{-}NO_3$	1	8.000	8.00	8.00	0.000
$N\text{-}NO_2$	2	8.000	2.40	13.60	5.600
$P\text{-}PO_4$	2	1.700	1.20	2.20	0.500
COD	2	149.500	123.00	176.00	26.500
TP	2	2.450	1.80	3.10	0.650
Cl^-	2	88.250	73.70	102.80	14.550
pH	1	8.000	8.00	8.00	0.000
K	2	141.750	137.50	146.00	4.250
Na	2	121.000	81.50	160.50	39.500
Ca	2	137.500	55.00	220.00	82.500
Mg	2	211.500	208.50	214.50	3.000
Cu	2	0.115	0.09	0.14	0.025
Zn	2	0.350	0.30	0.40	0.050
Fe	2	3.545	1.05	6.04	2.495
Al	2	2.900	0.70	5.10	2.200

TABLE A-70. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 446 - 160 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	2	78.000	32.00	124.00	46.000
TKN	2	42.000	0.00	84.00	42.000
$N\text{-}NH_4$	2	39.200	0.00	78.40	39.200
$N\text{-}NO_3$	2	50.250	37.50	63.00	12.750
$N\text{-}NO_2$	2	8.650	6.10	11.20	2.550
$P\text{-}PO_4$	2	3.600	1.60	5.60	7.000
C org	2	39.000	13.00	65.00	26.000
COD	2	204.500	127.00	282.00	77.500
TP	2	4.050	1.70	6.40	2.350
Cl^-	2	122.800	113.80	131.80	9.000
pH	1	7.600	7.60	7.60	0.000
K	2	154.000	134.50	173.50	19.500
Na	2	99.750	98.00	101.50	1.750
Ca	2	247.500	190.00	305.00	57.500
Mg	2	197.500	185.00	210.00	12.500
Cu	2	0.235	0.09	0.38	0.145
Zn	2	0.450	0.20	0.70	0.250
Fe	2	4.280	3.02	5.54	1.260
Al	2	3.410	2.24	4.58	1.170

TABLE A-71. CHARACTERISTICS OF WASTES FROM BLWRS INSIDE (CONCENTRATIONS OF POLLUTANTS EXPRESSED IN PPM; WASTE VOLUME IN LITERS)

Location 447 - 160 cm Depth, Two Points in BLWRS - 4
Time Period - 01/01/81 to 12/31/81

Parameter	Number of Observations	Average Value	Minimum Value	Maximum Value	Standard Deviation
SS	4	77.750	18.00	170.00	56.464
TKN	4	67.200	42.00	92.40	18.254
$N-NH_4$	4	63.700	42.00	86.80	16.609
$N-NO_3$	4	166.875	57.50	235.00	71.181
$N-NO_2$	4	4.475	0.00	8.00	2.894
$P-PO_4$	4	1.550	0.70	2.20	0.626
C org	3	76.167	29.00	112.50	34.939
COD	4	118.250	75.00	160.00	32.927
TP	4	1.650	0.80	2.20	0.589
Cl^-	4	123.300	113.60	135.10	8.166
pH	3	7.633	7.20	8.10	0.368
K	2	155.250	148.00	162.50	7.250
Na	2	150.750	128.50	173.00	22.250
Ca	2	197.500	135.00	260.00	62.500
Mg	2	232.500	221.00	244.00	11.500
Cu	2	0.120	0.06	0.18	0.060
Zn	2	0.650	0.30	1.00	0.350
Fe	2	3.680	0.62	6.74	3.060
Al	2	2.735	0.25	5.22	2.485

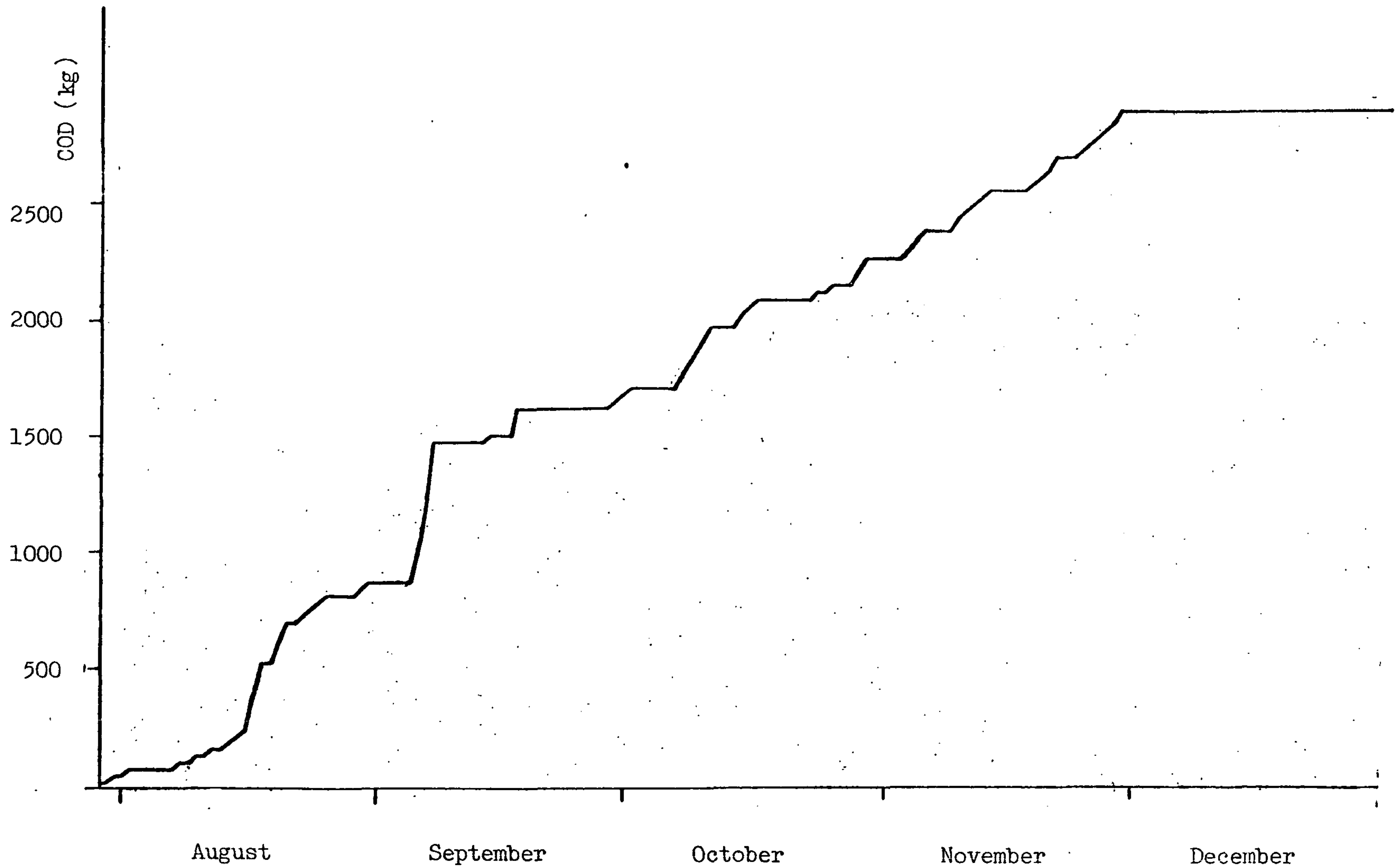


Figure A-1. Cumulative COD load in BLWRS-1 or BLWRS-2 influent
For the period of 07/30/79 - 12/31/79.

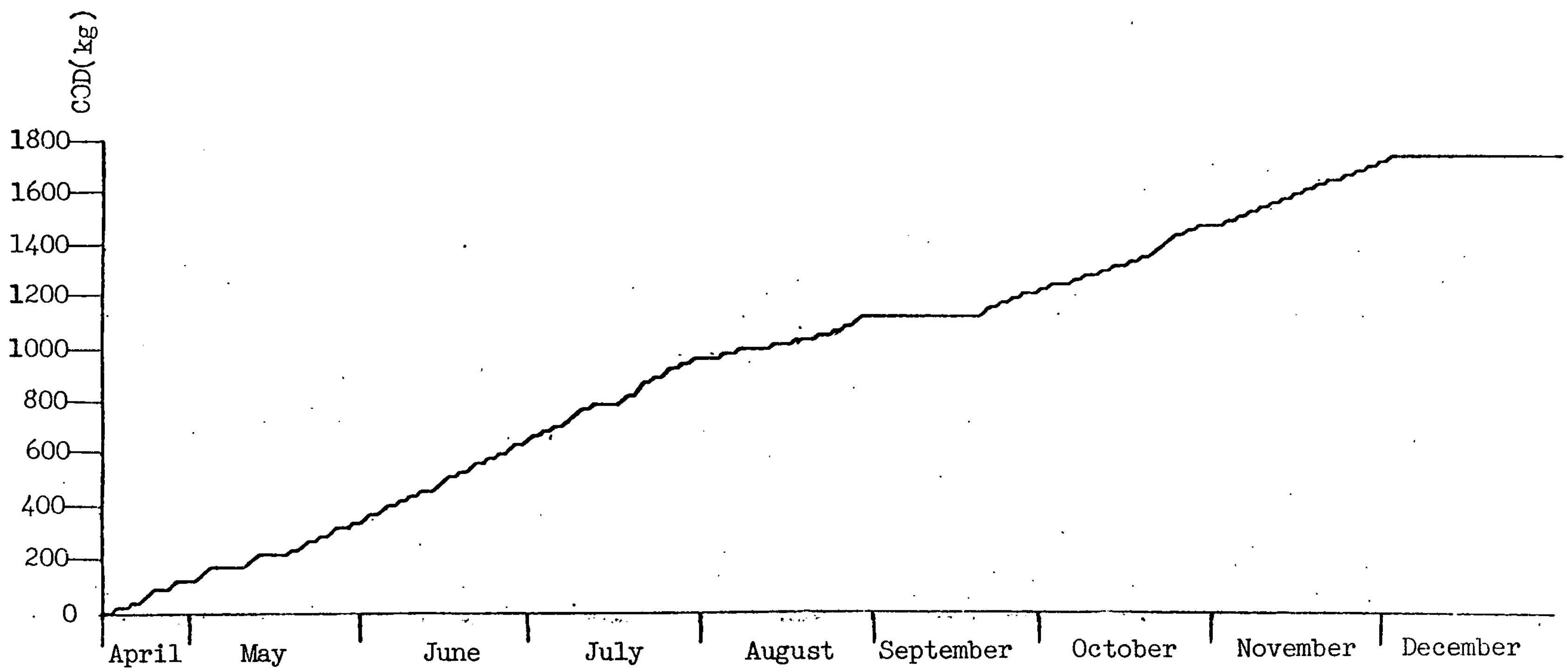


Figure A-2. Cumulative COD load in BLWRS-1 or BLWRS-2 influent for the period of 04/16/80 - 12/31/80.

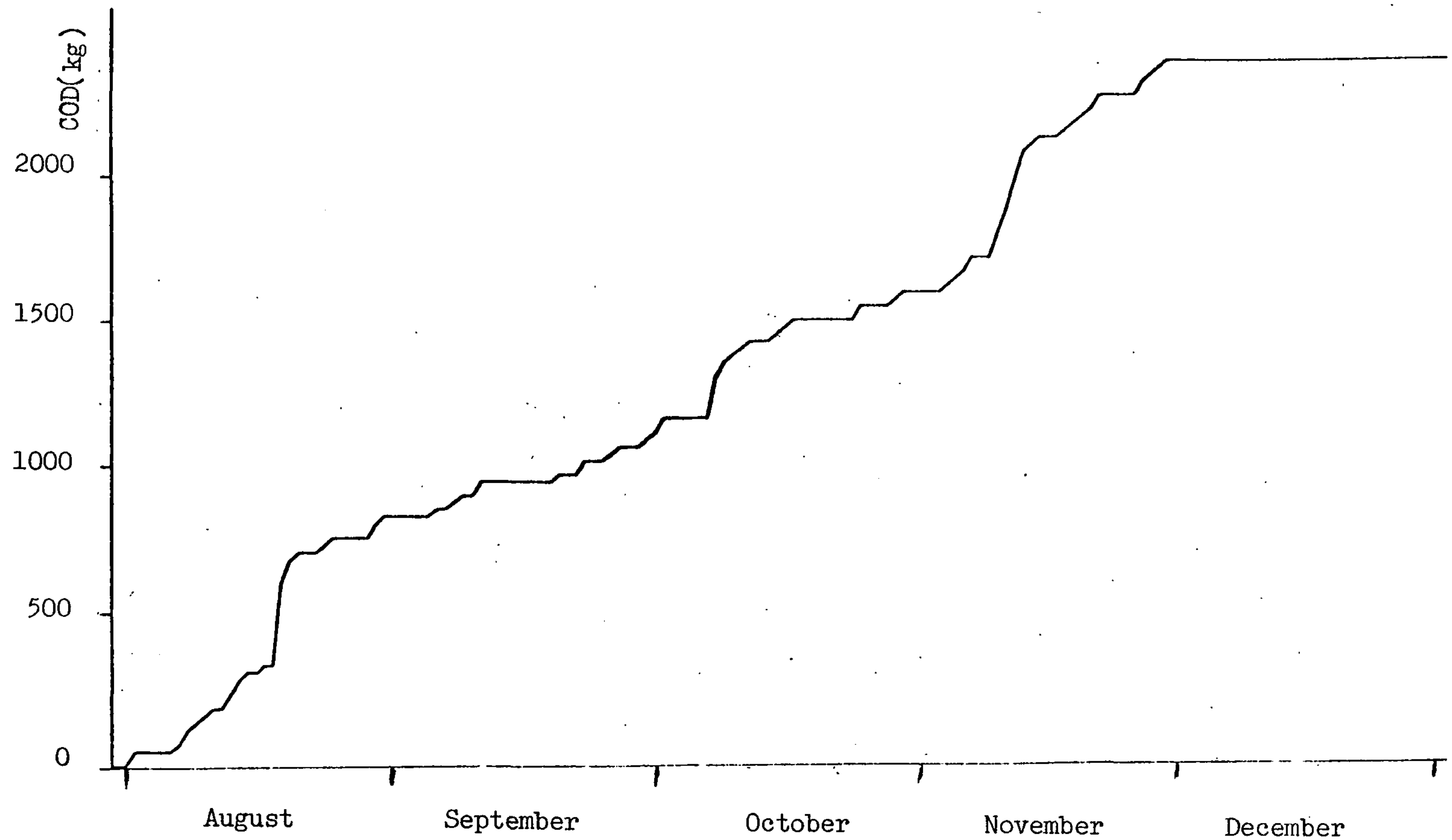


Figure A-3. Cumulative COD load in BLWRS-3 or BLWRS-4 influent for the period of 07/31/79 - 12/31/79.

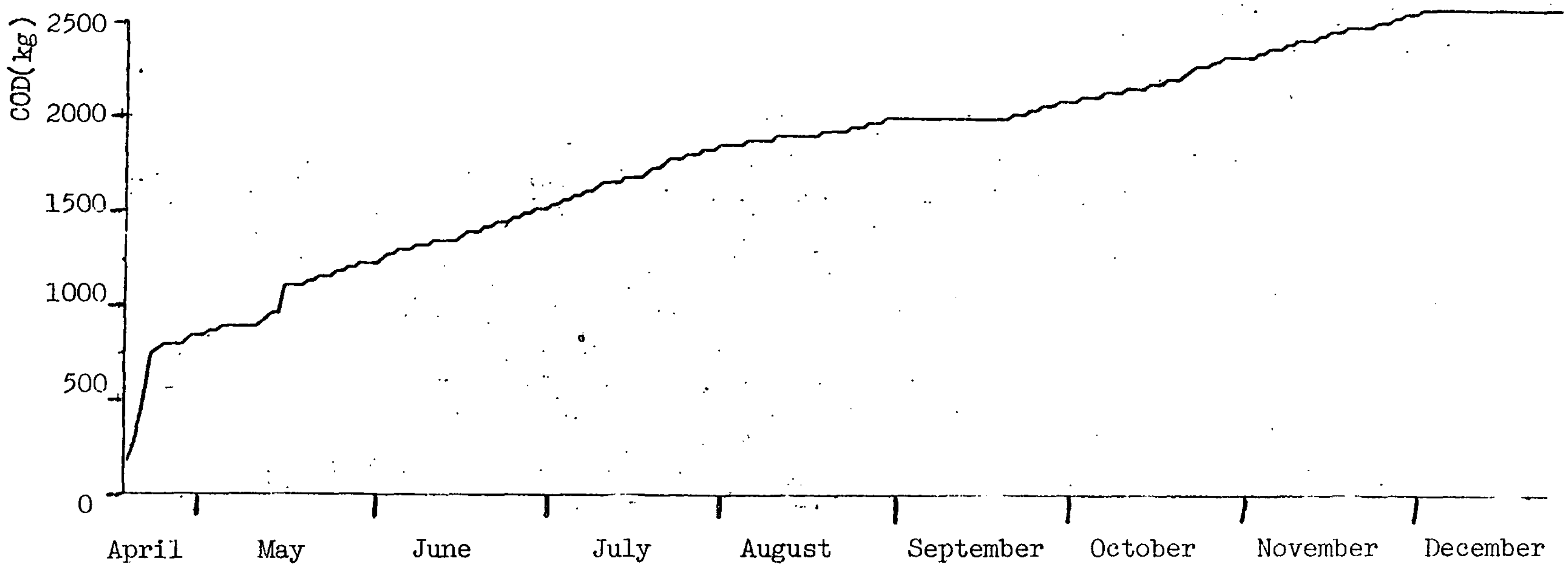


Figure A-4. Cumulative COD load in BLWRS-3 or BLWRS-4 influent for the period of 04/19/80 - 12/31/80.

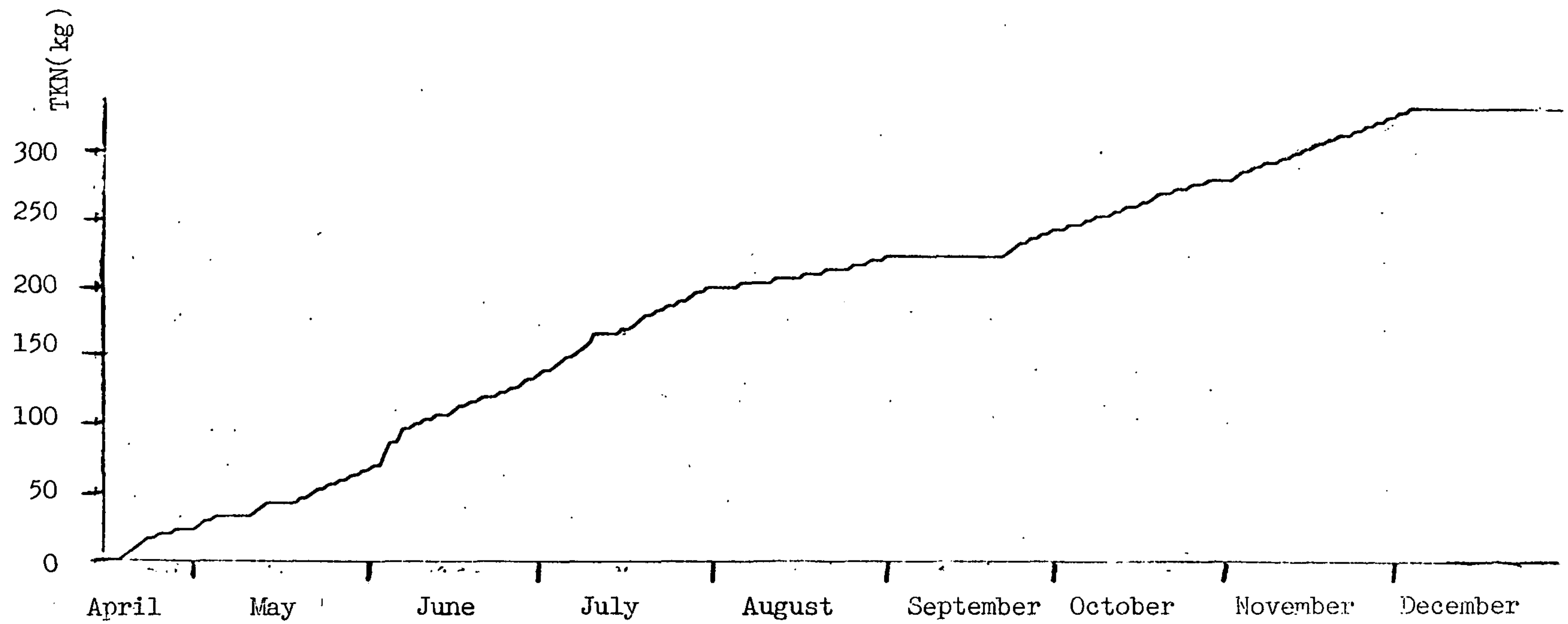


Figure A-6. Cumulative TKN load in BLWRS-1 or BLWRS-2 influent for the period of 04/16/80 - 12/31/80.

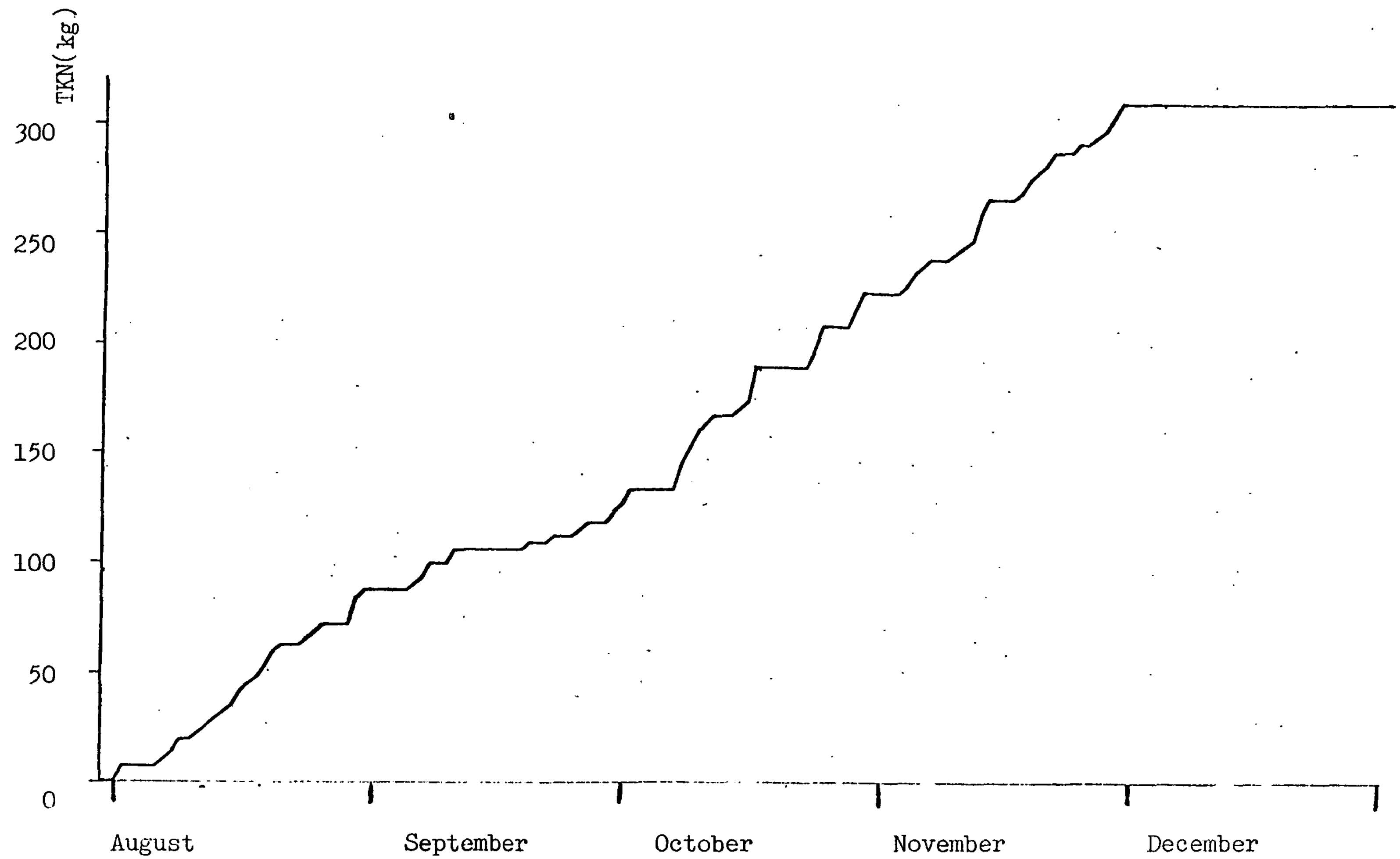


Figure A-7. Cumulative TKN load in BLWRS-3 or BLWRS-4 influent for the period of 07/31/79 - 12/31/79.

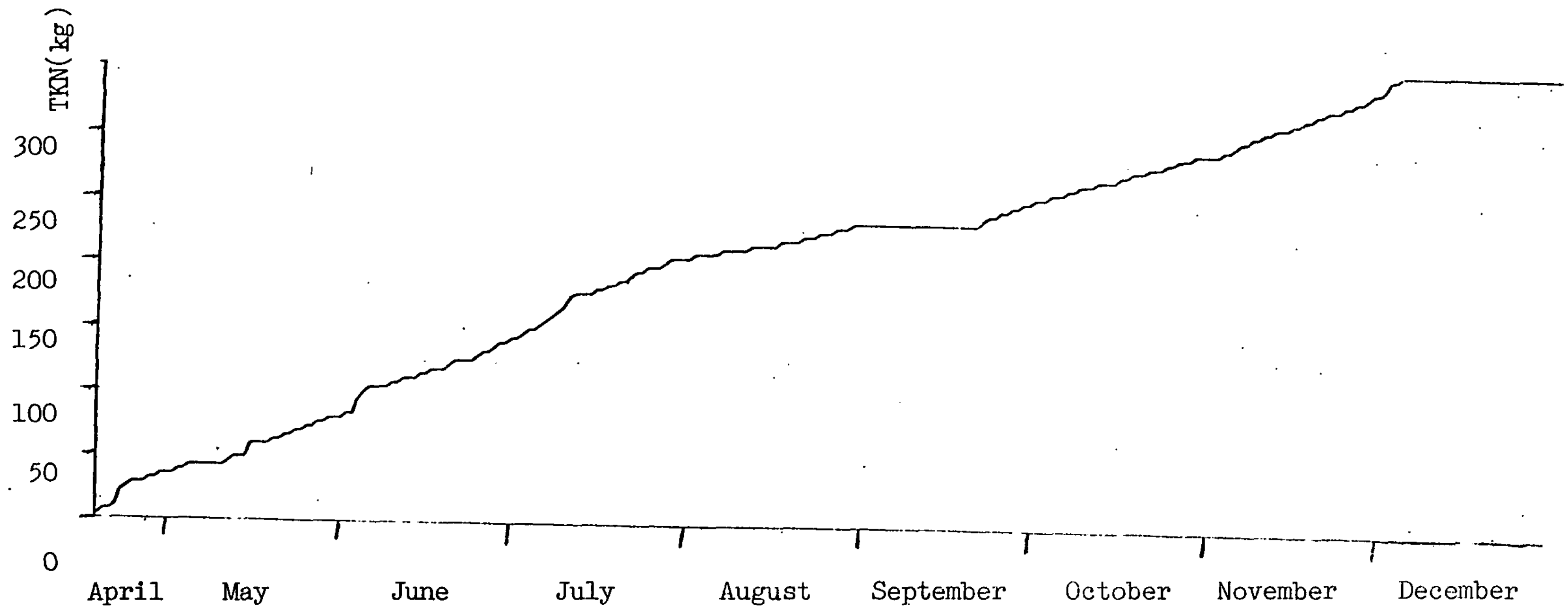


Figure A-8. Cumulative TKN load in BLWRS-3 or BLWRS-4 influent
for the period of 04/19/80 - 12/31/80.

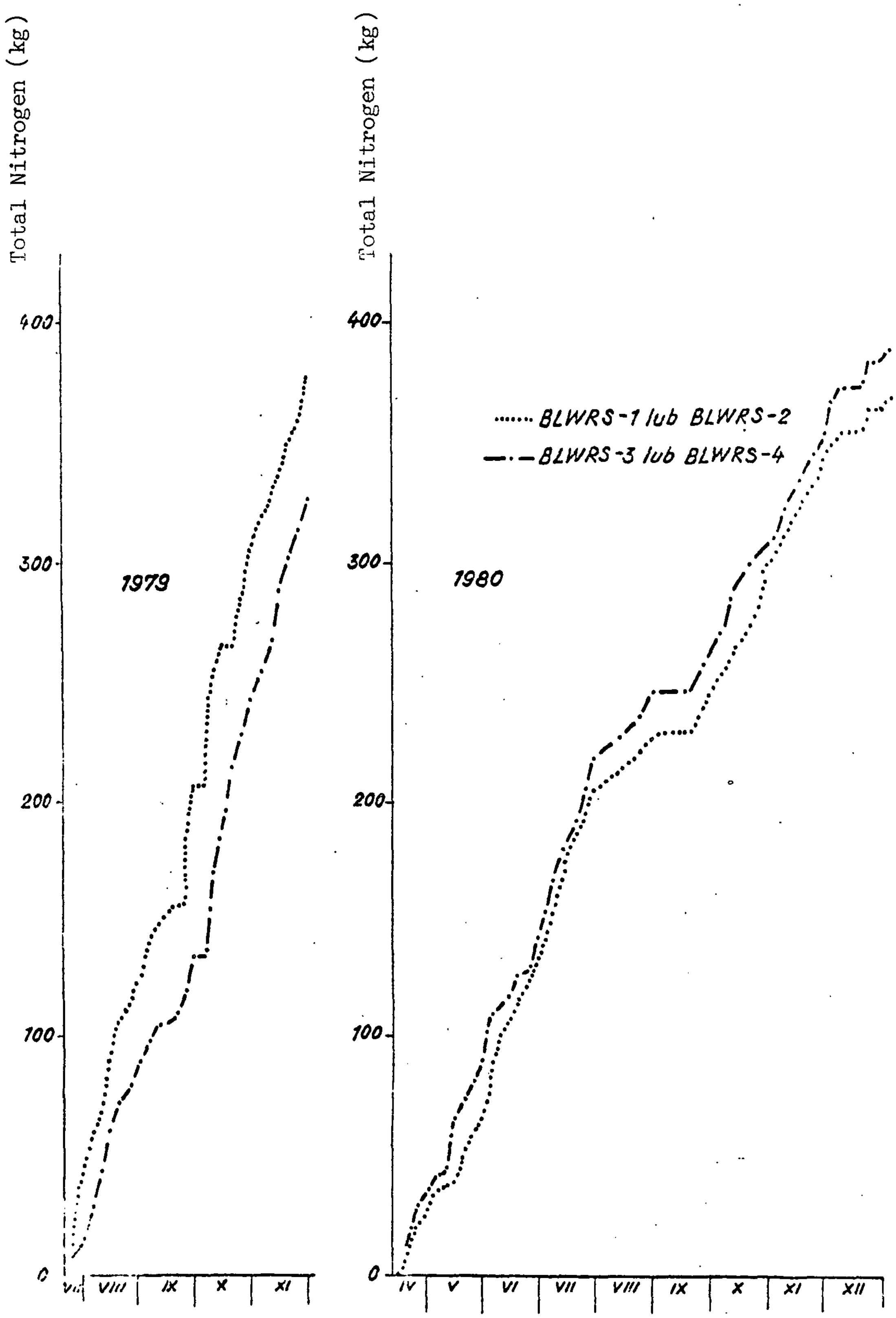


Figure A-9. Cumulative TN load in BLWRS influent.

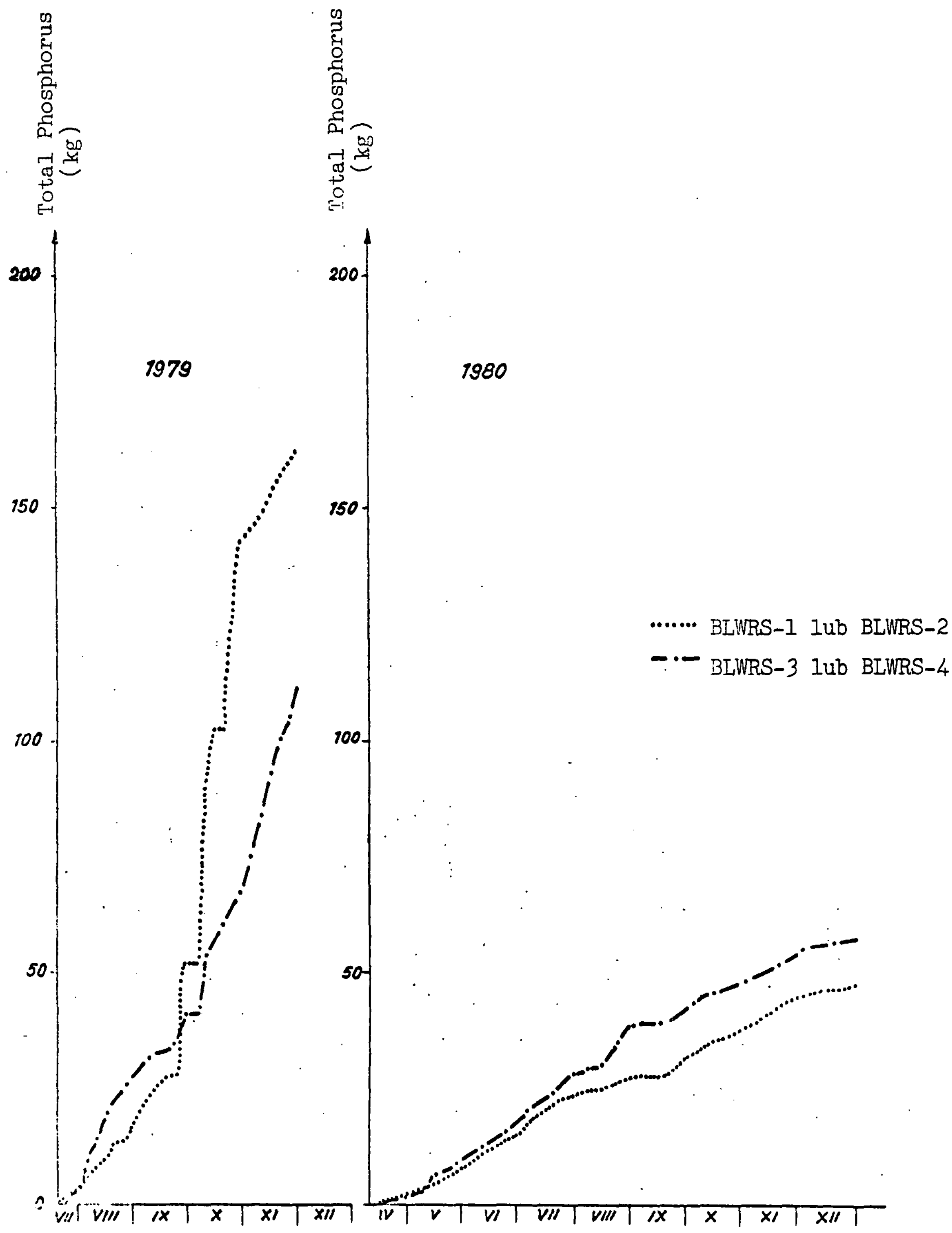


Figure A-10. Cumulative total phosphorus load in BLWRS influent.

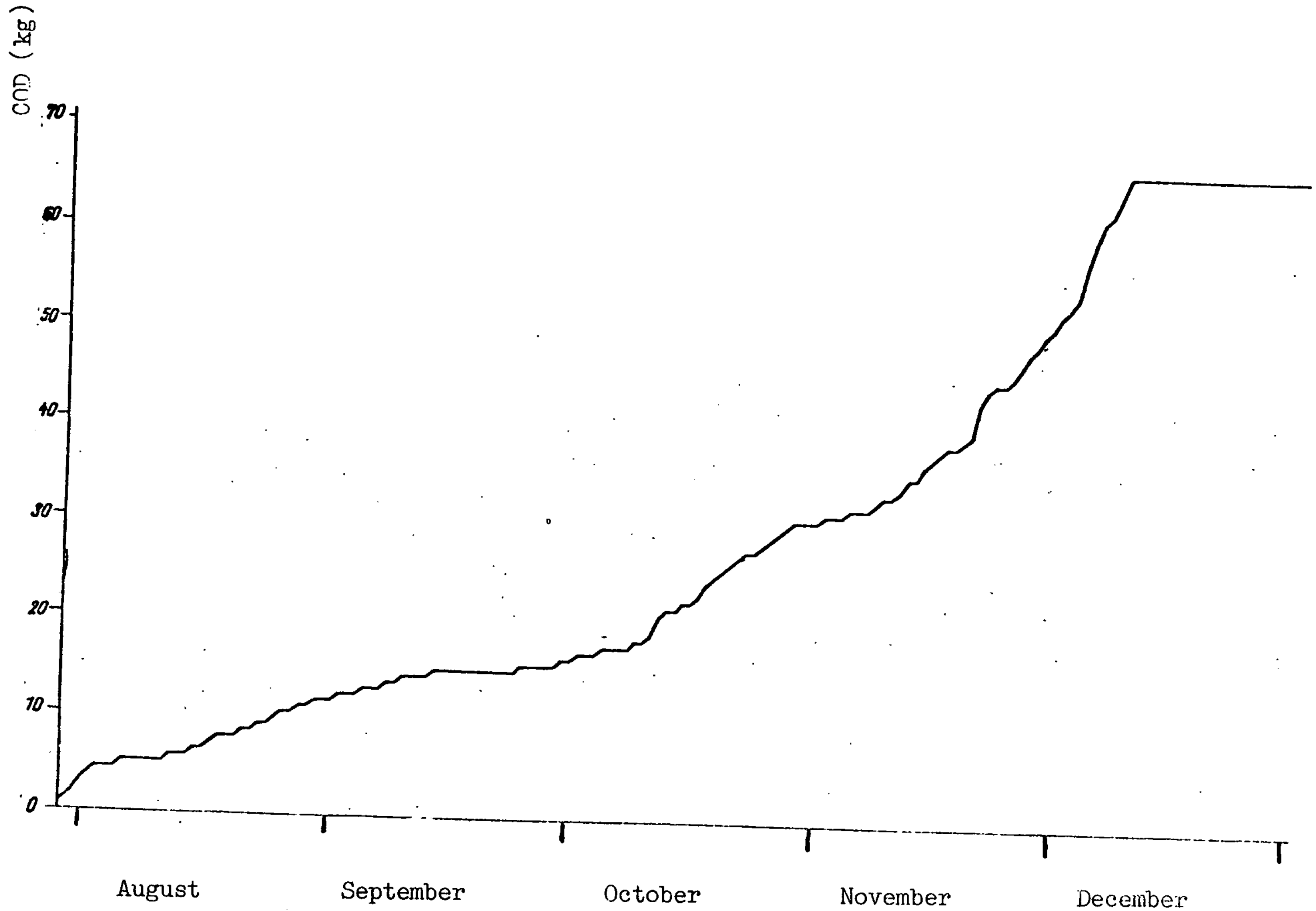


Figure A-11. Cumulative COD load in BLWRS-1 effluent for the period of 07/30/79 - 12/31/79.

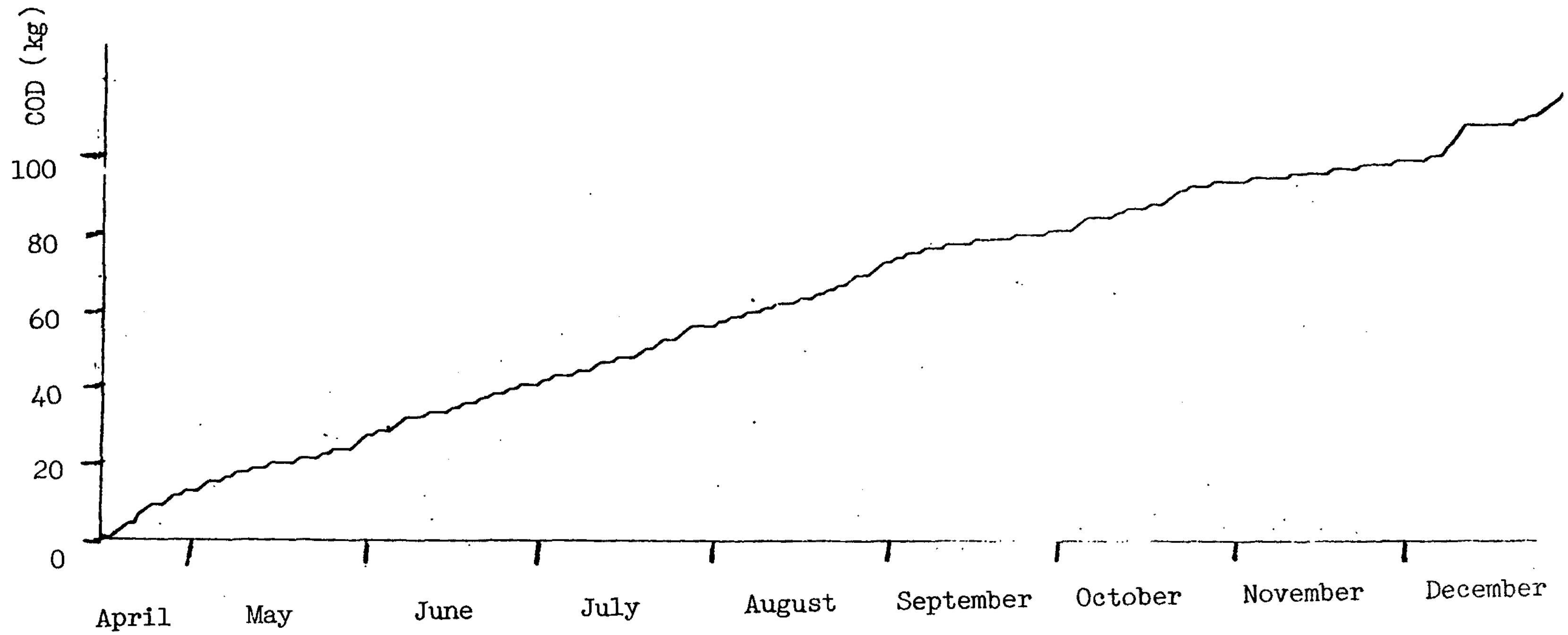


Figure A-12. Cumulative COD load in BLWRS-1 effluent for the period of 04/16/80 - 12/31/80.

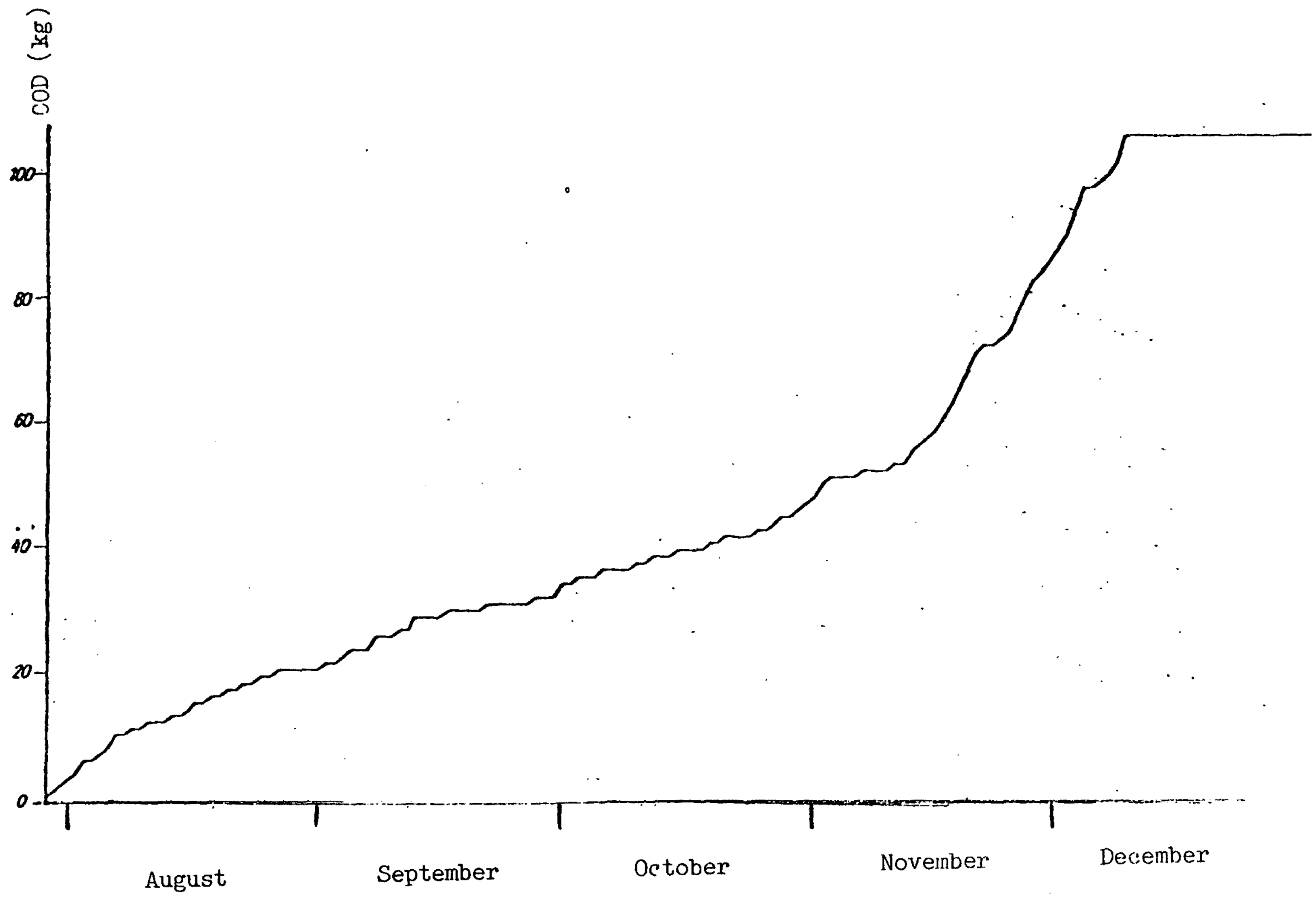


Figure A-13. Cumulative COD load in BLWRS-2 effluent for the period of 07/30/79 - 12/31/79.

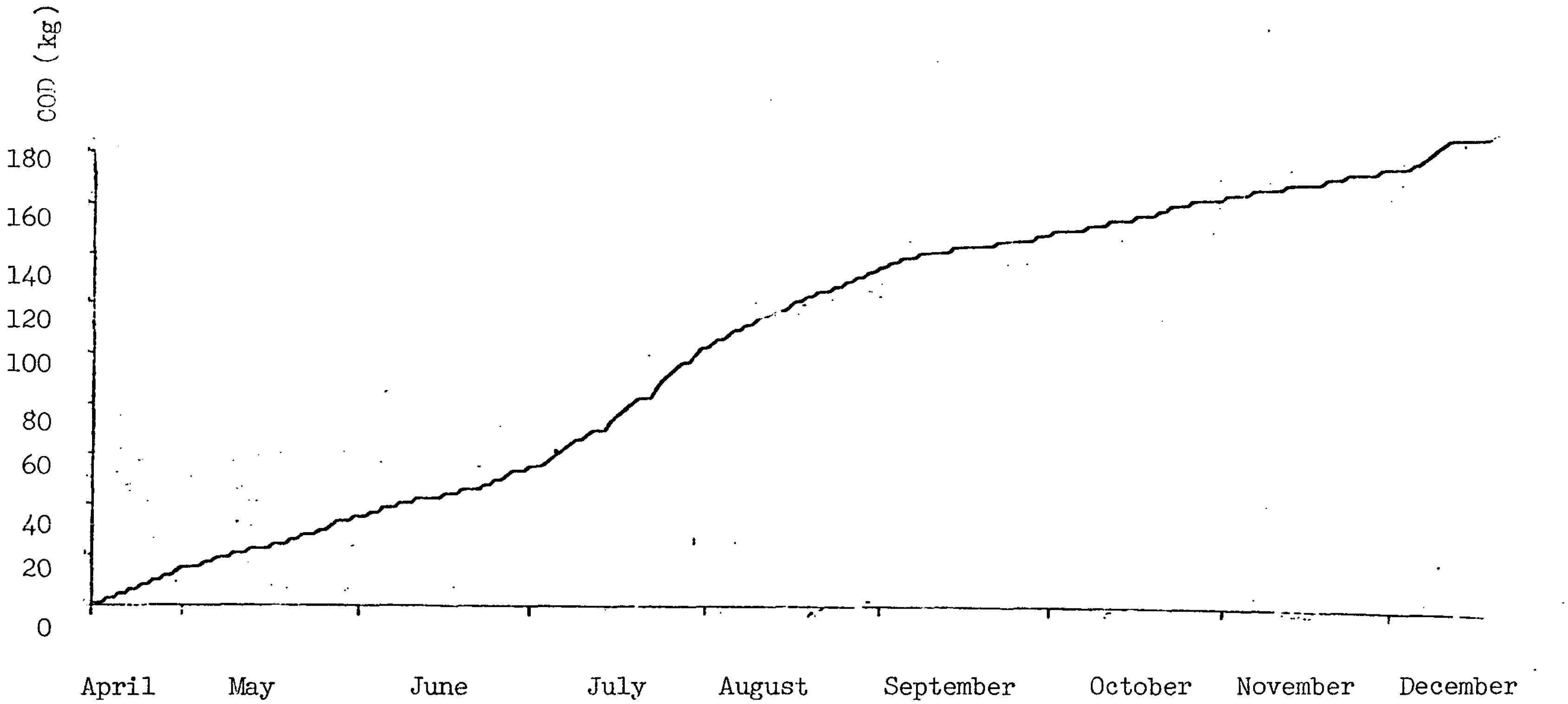


Figure A-14. Cumulative COD load in BLWRS-2 effluent for the period of 04/16/80 - 12/31/80.

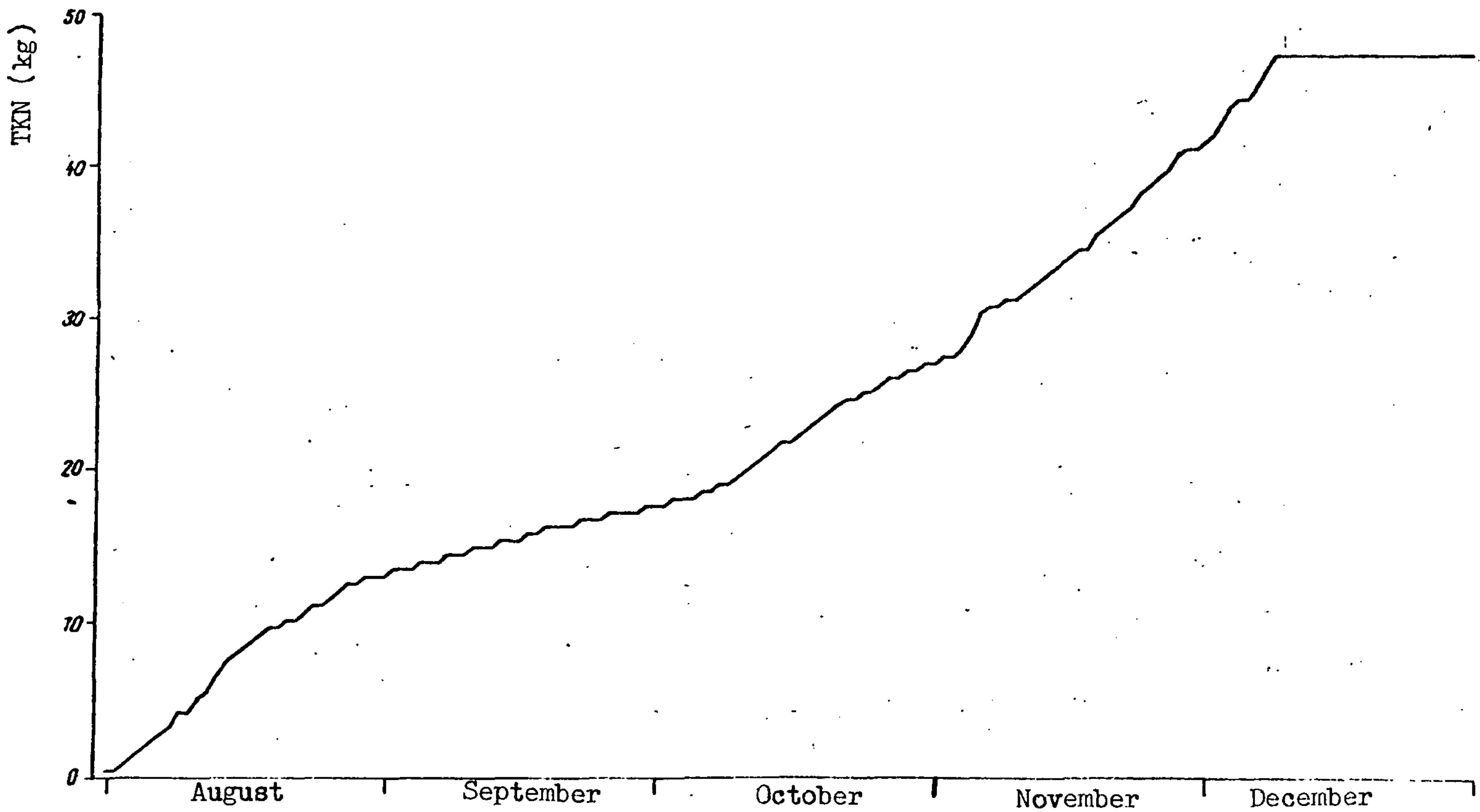


Figure A-15. Cumulative COD load in BLWRS-3 effluent for the period of 07/31/79 - 12/31/79.

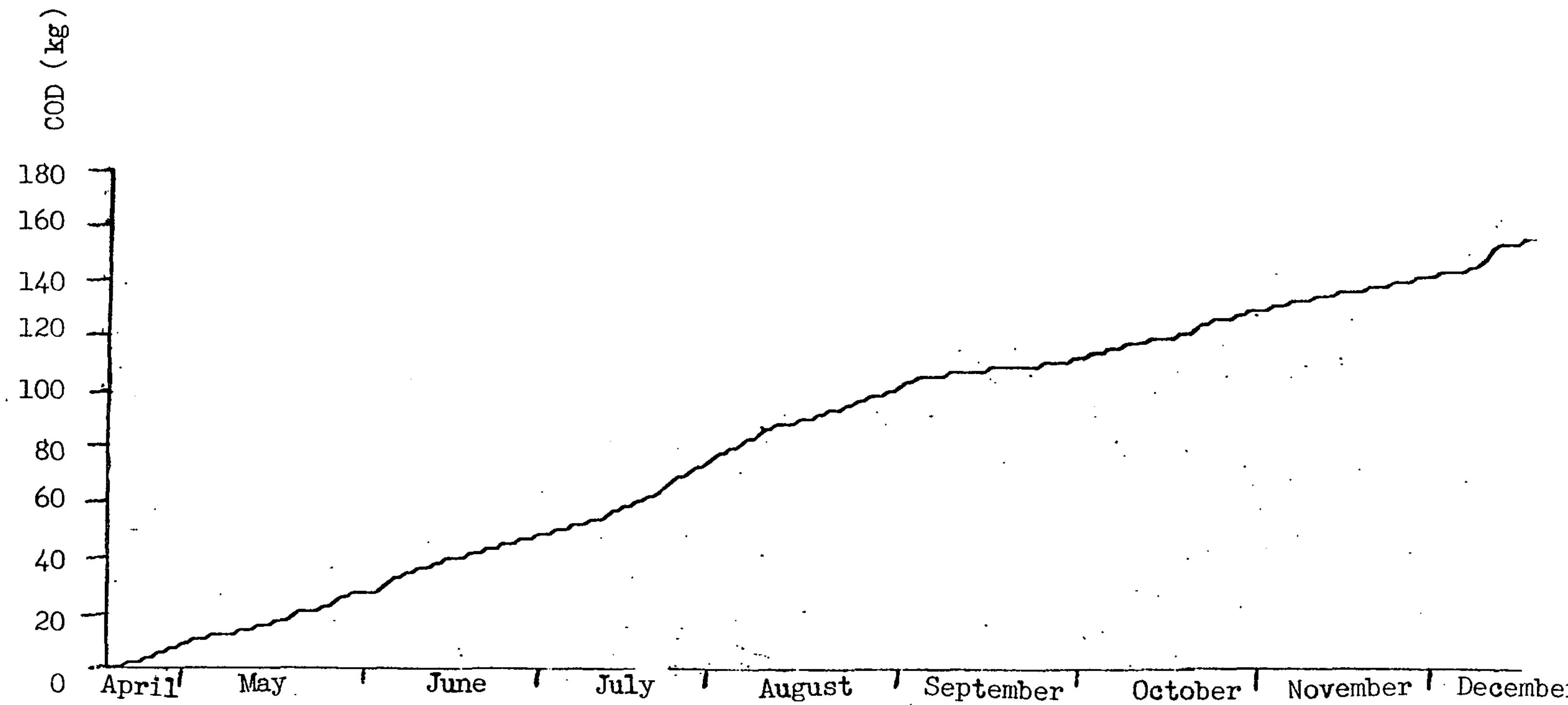


Figure A-16. Cumulative COD load in BLWRS-3 effluent for the period of 04/19/80 - 12/31/80.

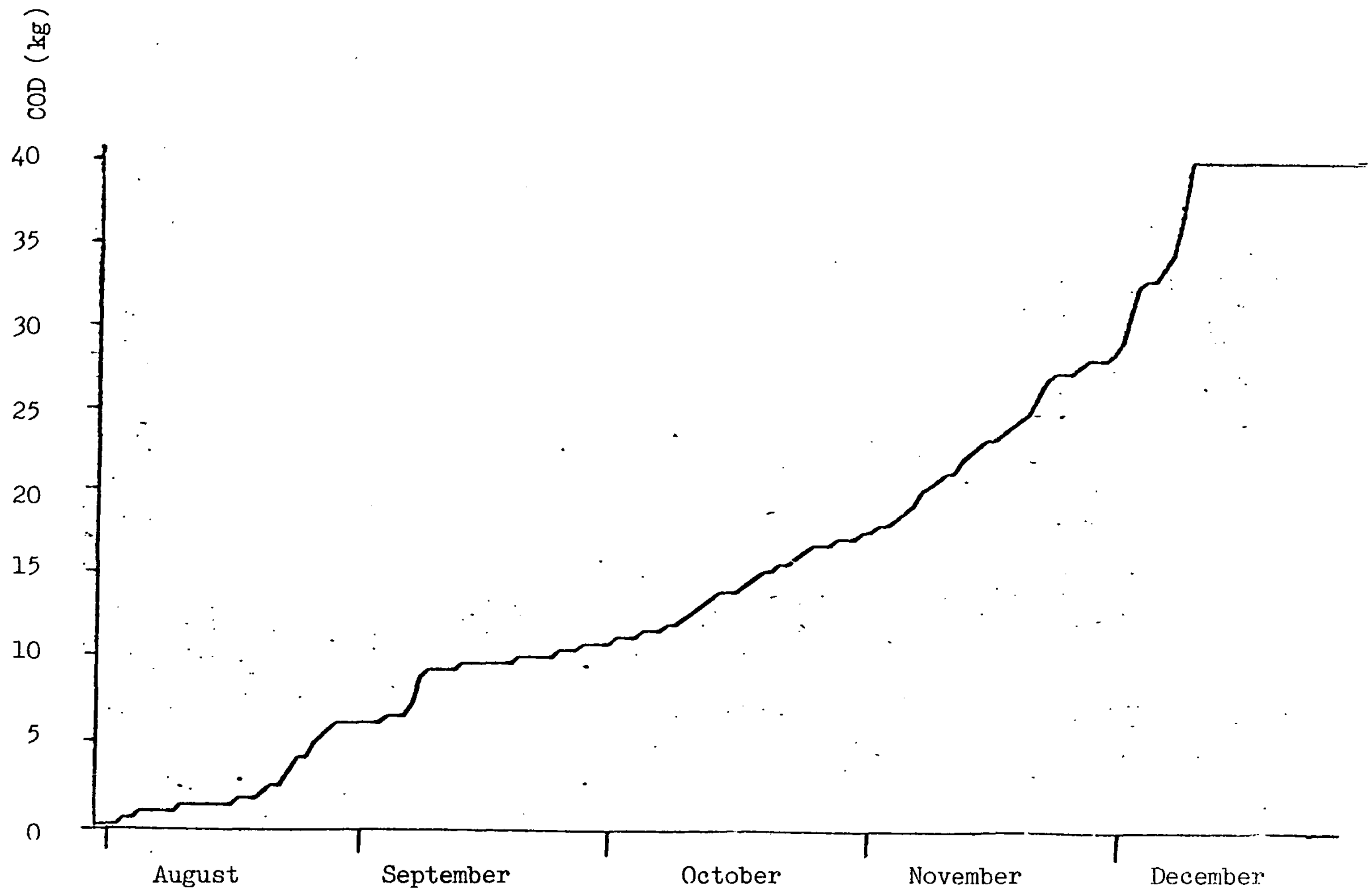


Figure A-17. Cumulative COD load in BLWRS-4 effluent for the period of 07/31/79 - 12/31/79.

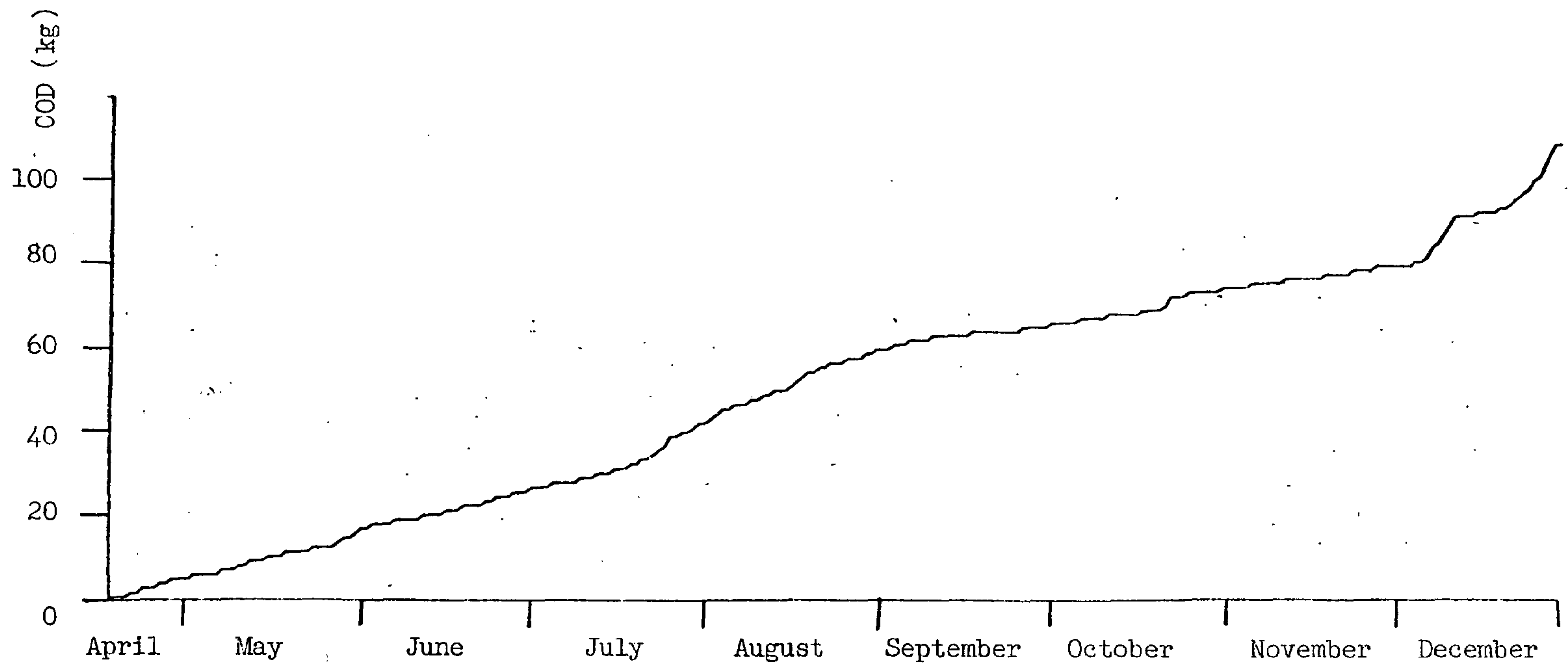


Figure A-18. Cumulative COD load in BLWRS-4 effluent for the period of 04/19/80 - 12/31/80.

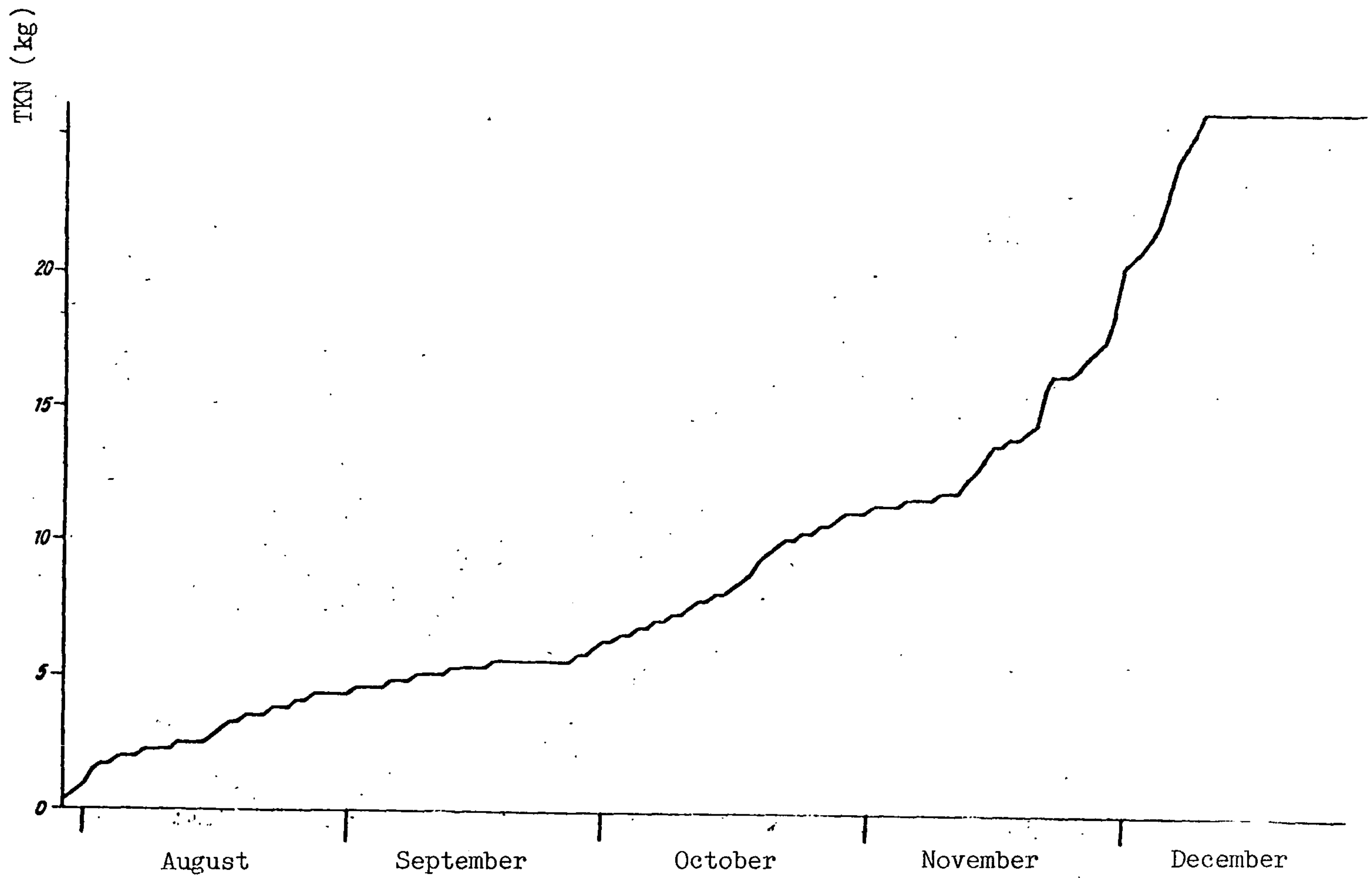


Figure A-19. Cumulative TKN load in BLWRS-1 effluent for the period of 07/30/79 - 12/31/79.

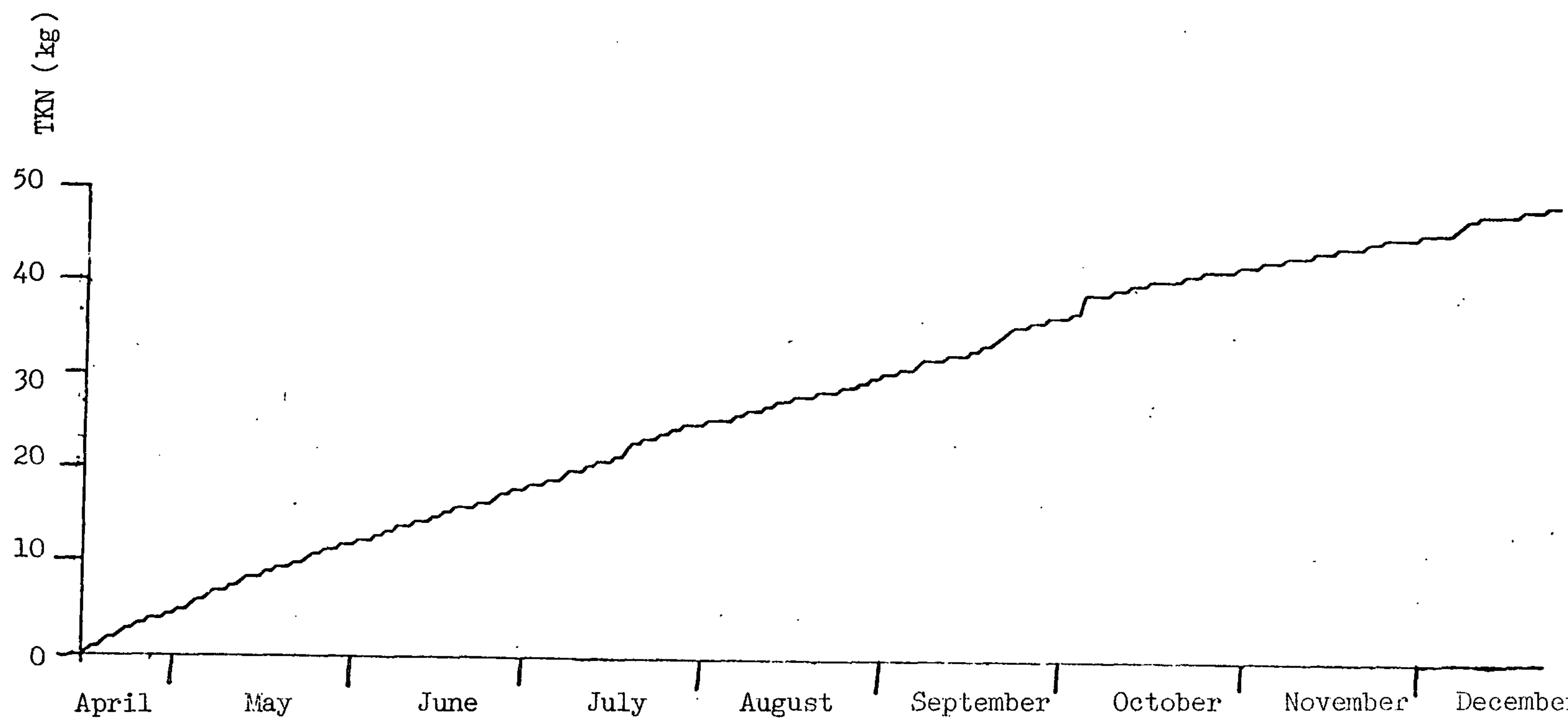


Figure A-20. Cumulative TKN load in BLWRS-1 effluent for the period of 04/16/80 - 12/31/80.

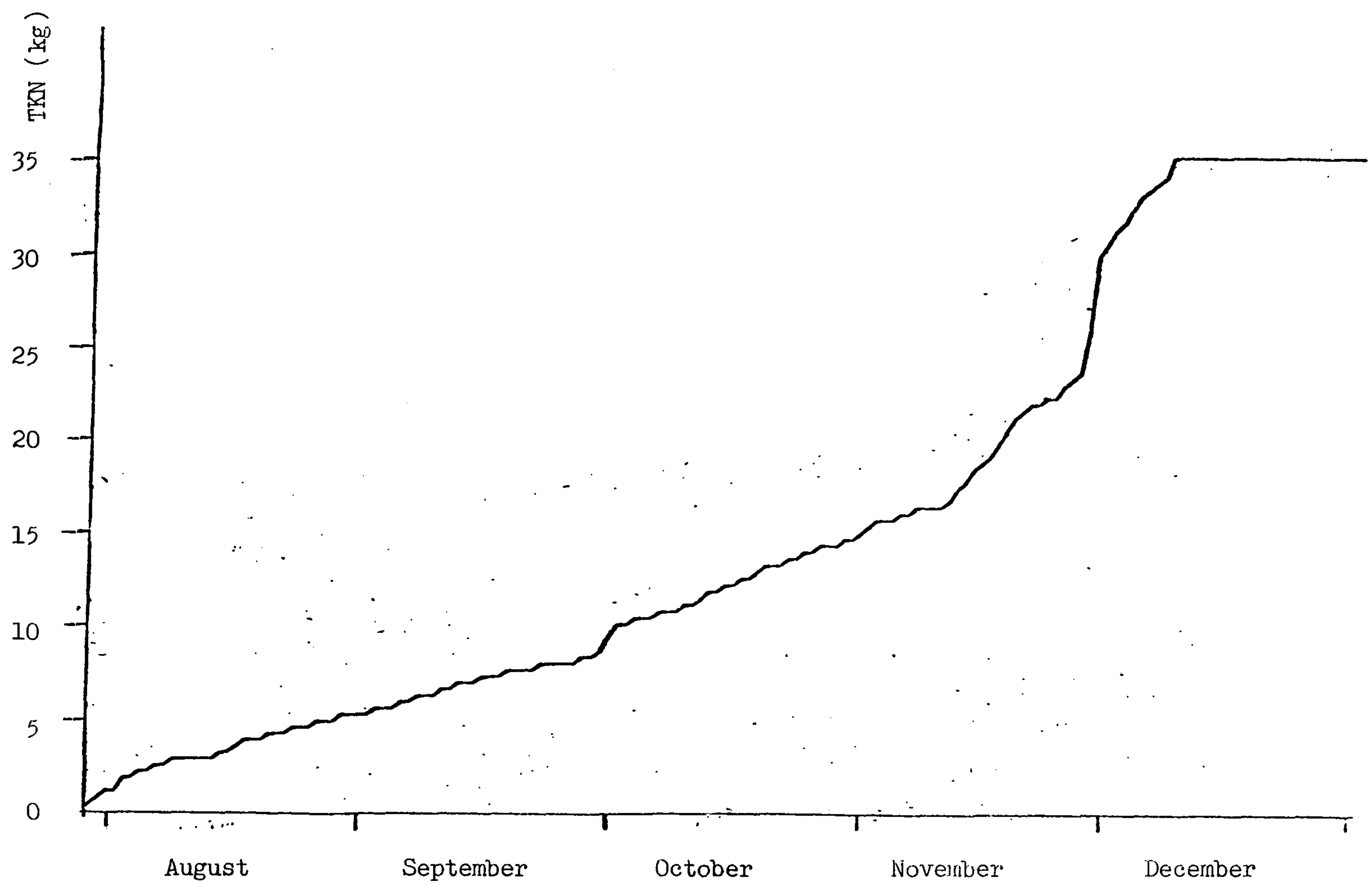


Figure A-21. Cumulative TKN load in BLWRS-2 effluent for the period of 07/30/79 - 12/31/79.

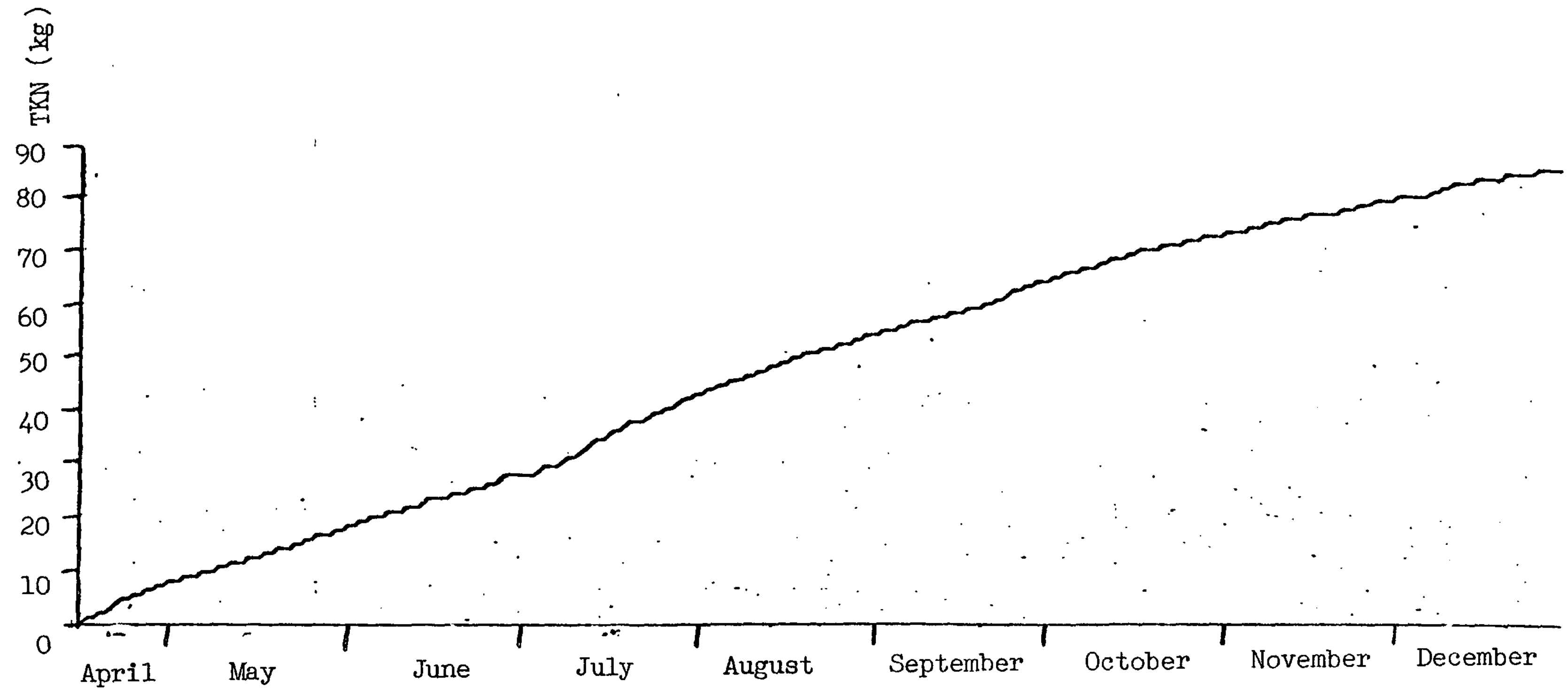


Figure A-22. Cumulative TKN load in BLWRS-2 effluent for the period of 04/16/80 - 12/31/80.

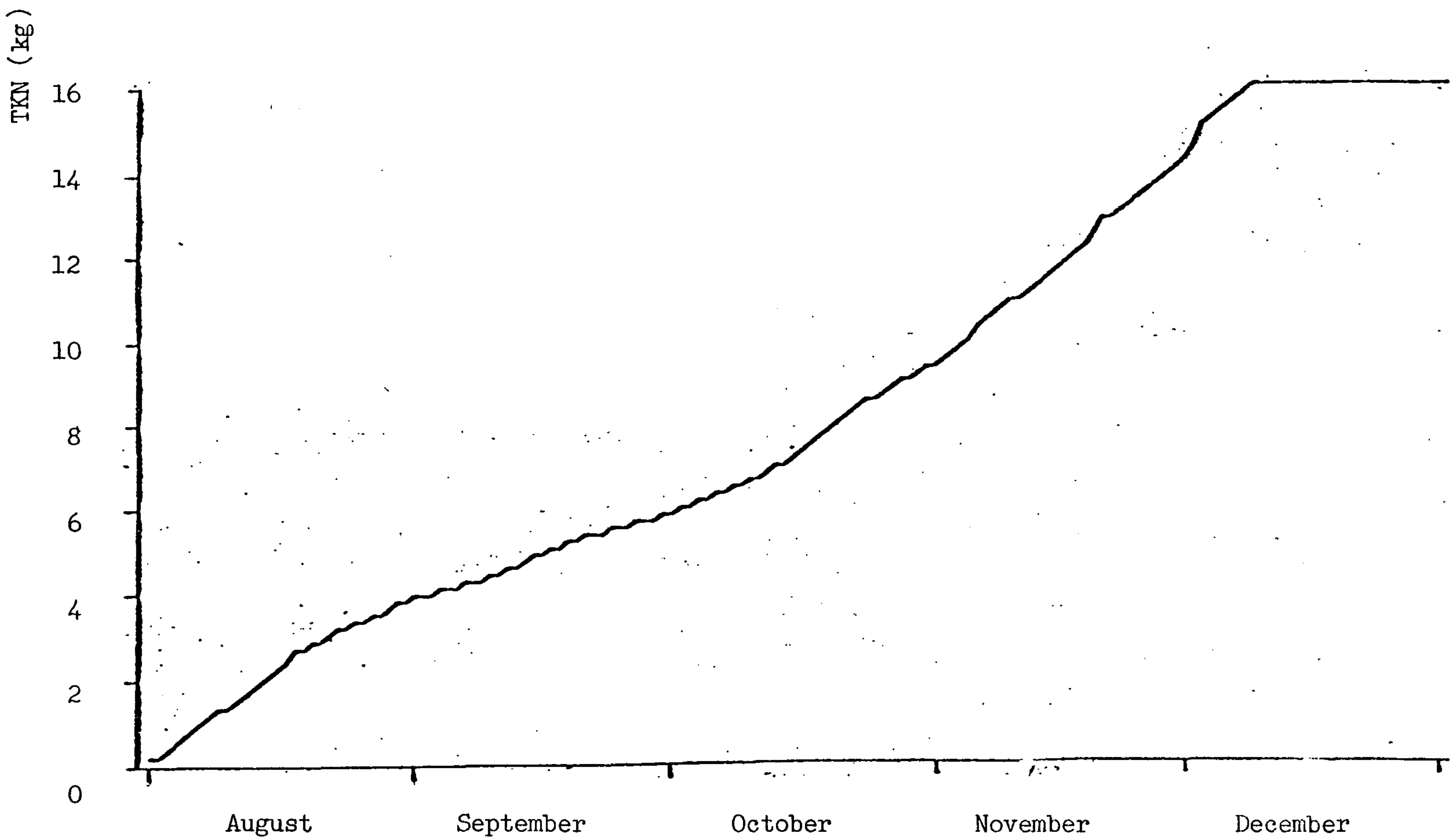


Figure A-23. Cumulative TKN load in BLWRS-3 effluent for the period of 07/31/79 - 12/31/79.

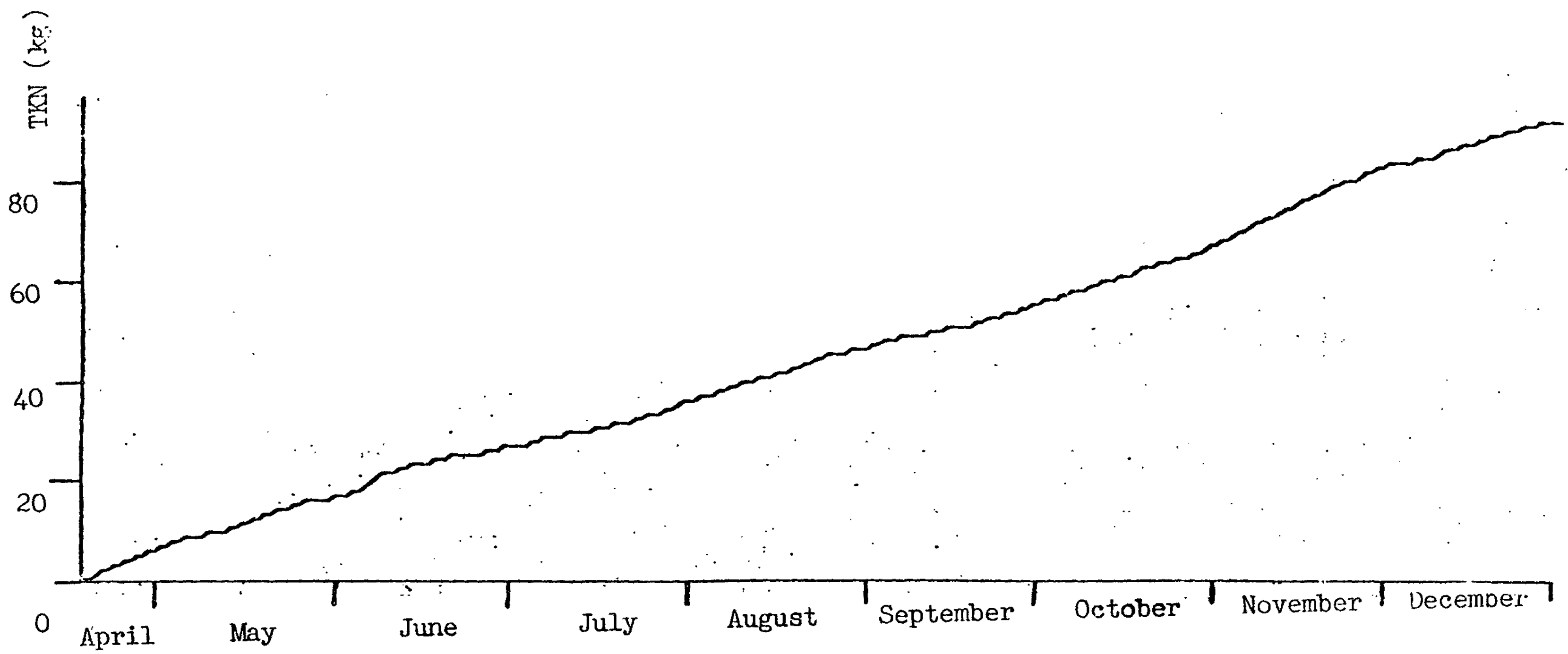


Figure A-24. Cumulative TKN load in BLWRS-3 effluent for the period of 04/19/80 - 12/31/80.

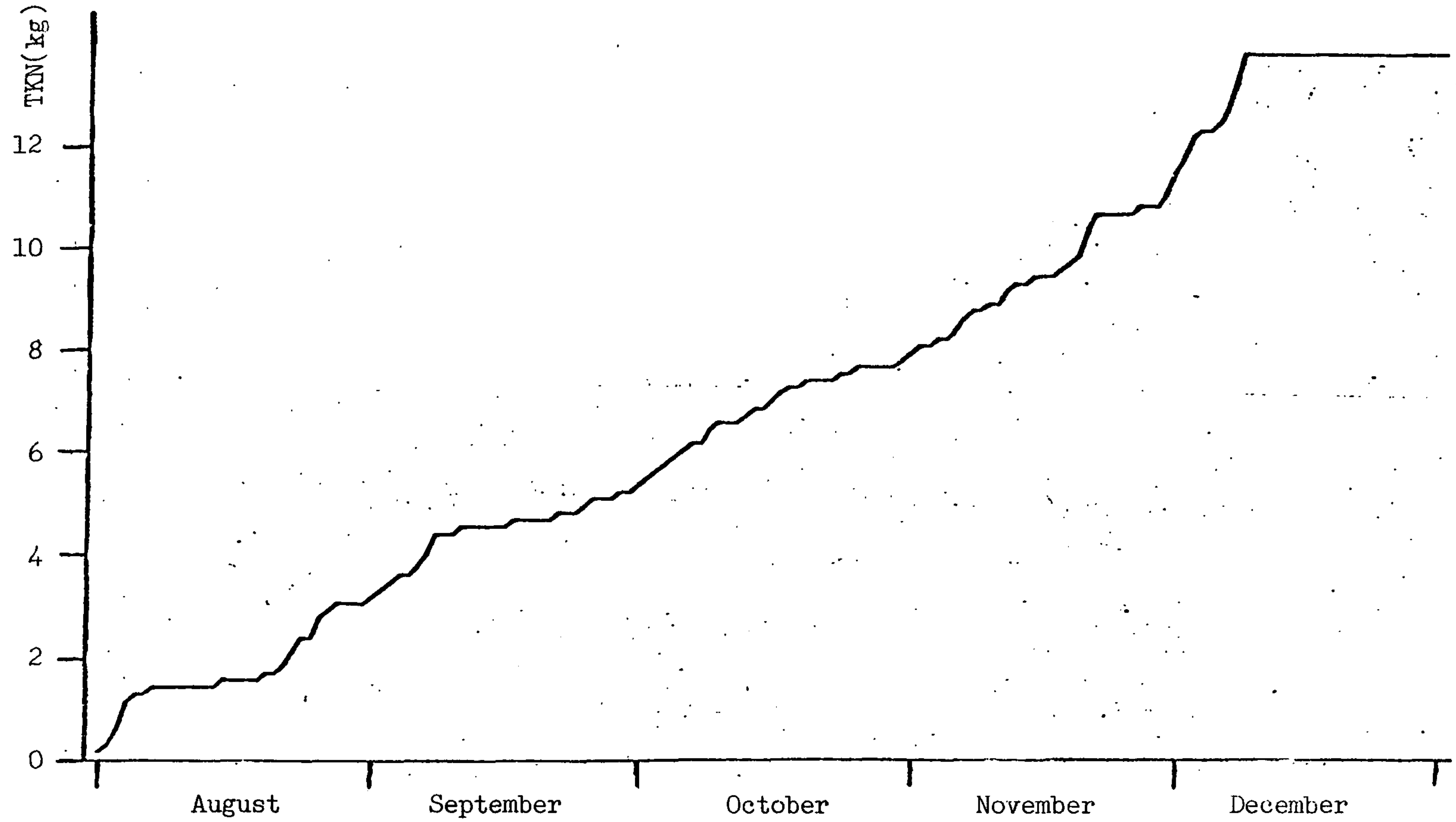


Figure A-25. Cumulative TKN load in BLWRS-4 effluent for the period of 07/31/79 - 12/31/79.

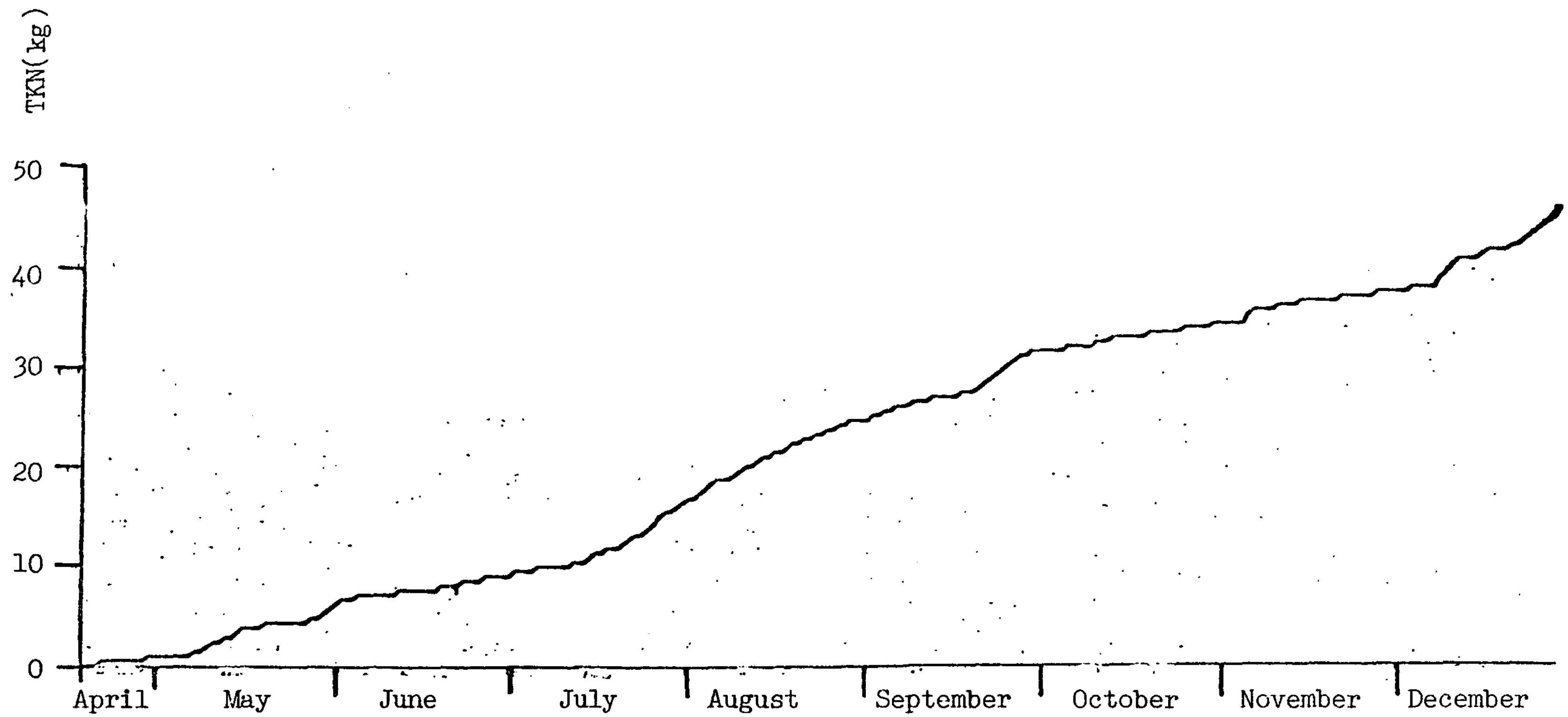


Figure A-26. Cumulative TKN load in BLWRS-4 effluent
for the period of 04/19/80 - 12/31/80.

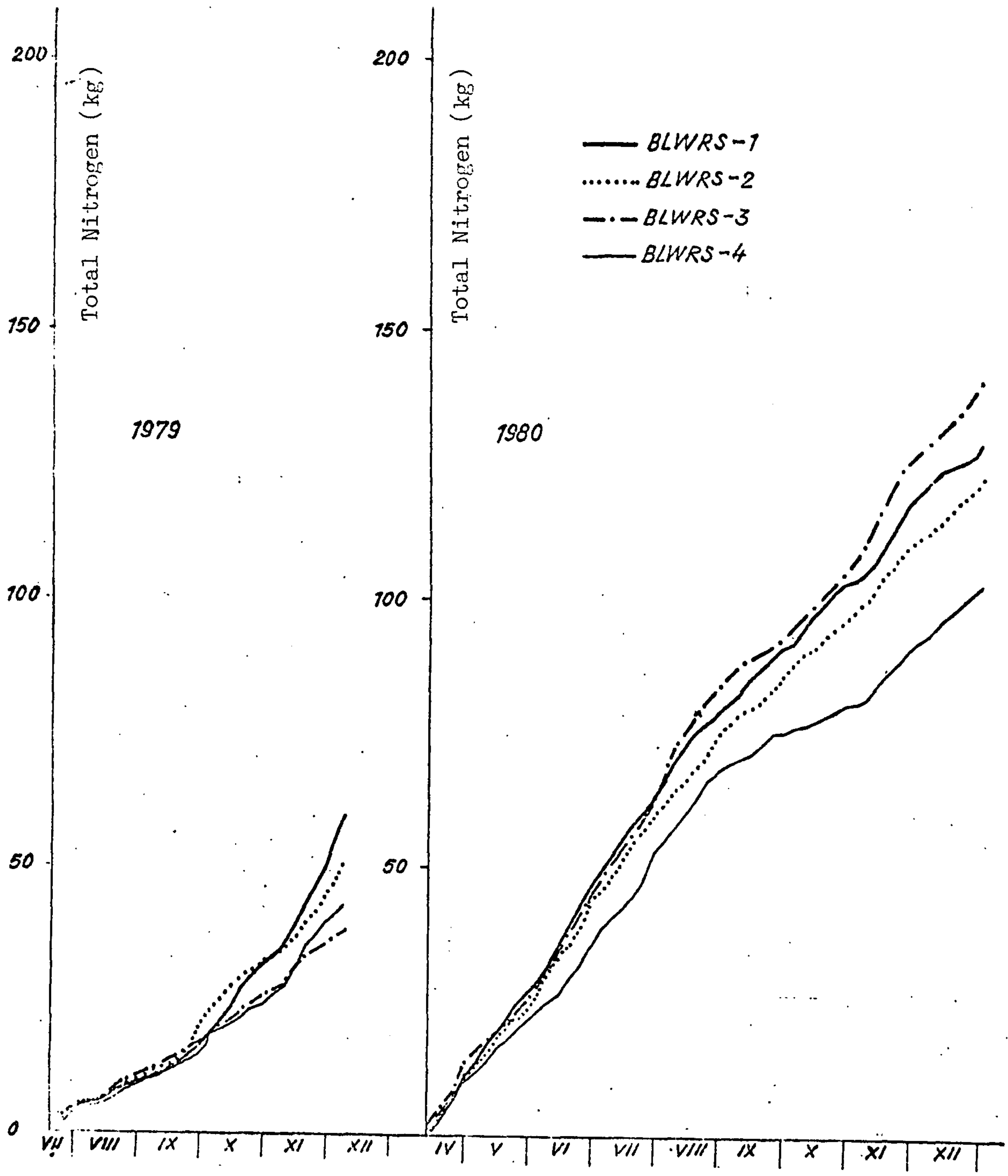


Figure A-27. Cumulative TN load in BLWRS effluent.

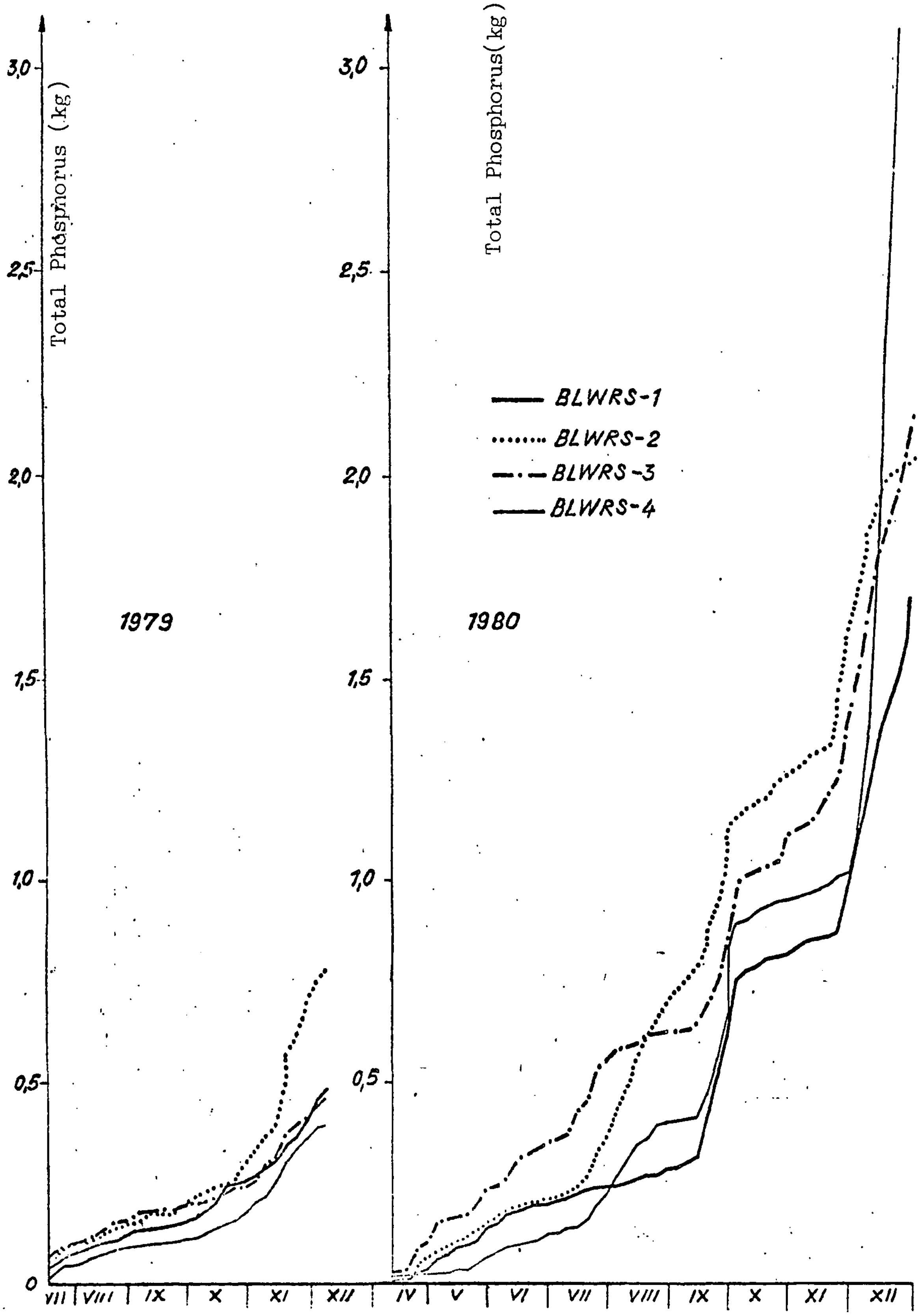


Figure A-28. Cumulative total phosphorus load in BLWRS effluent.

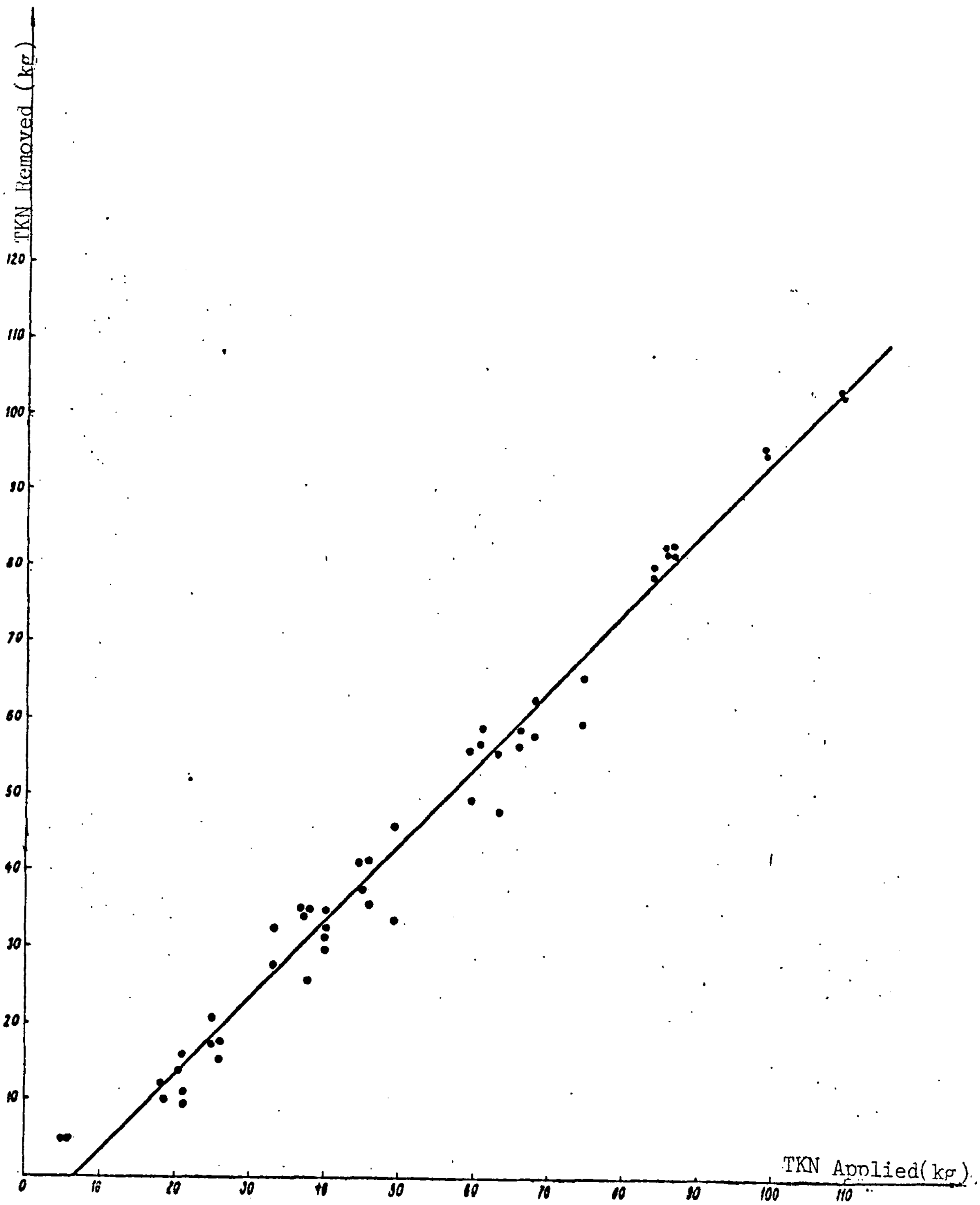


Figure A-29. Relationship between removed and applied monthly TKN loading in the case of BLWRS.

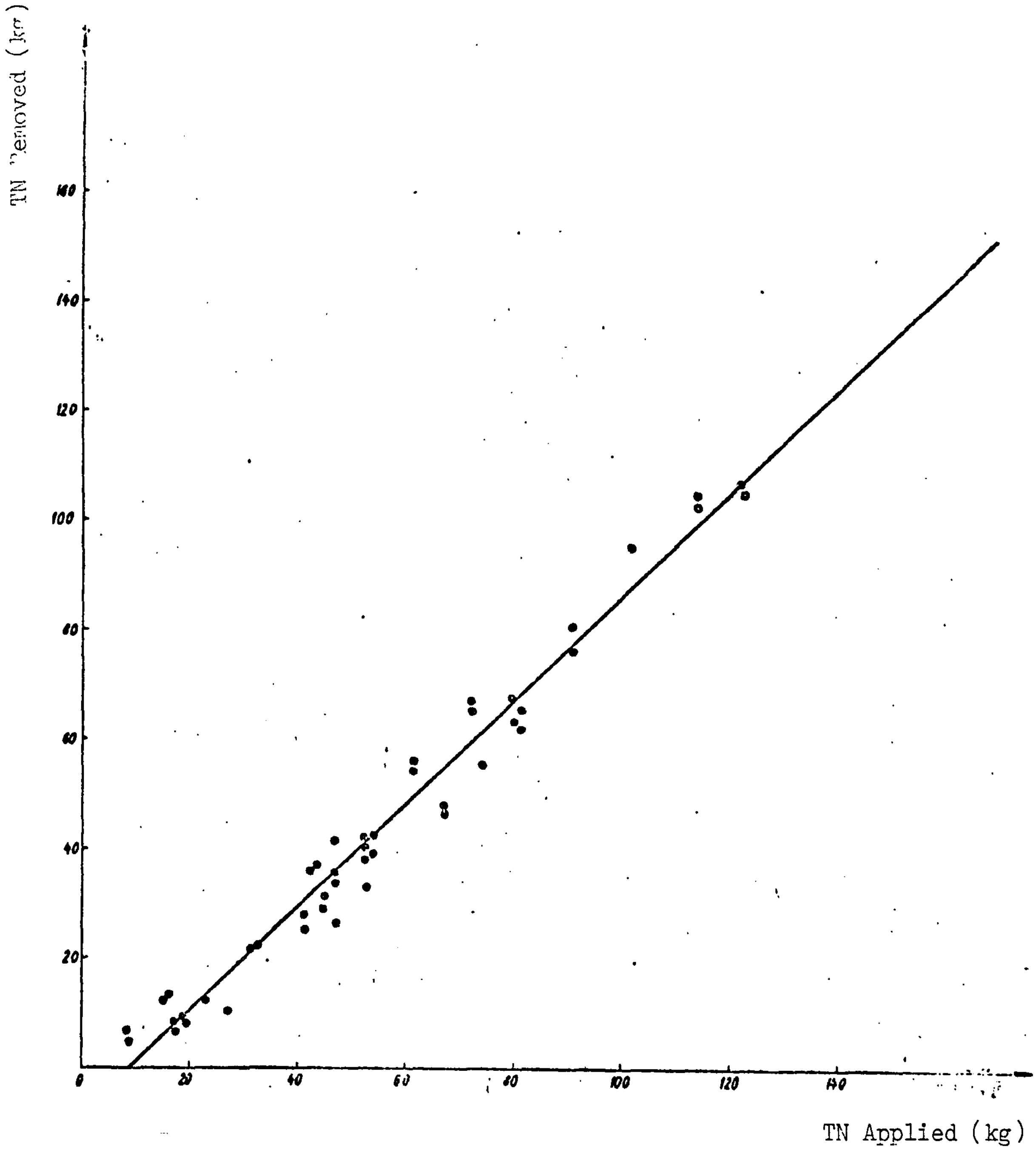


Figure A-30. Relationship between removed and applied monthly TN loading in the case of BLWRS.

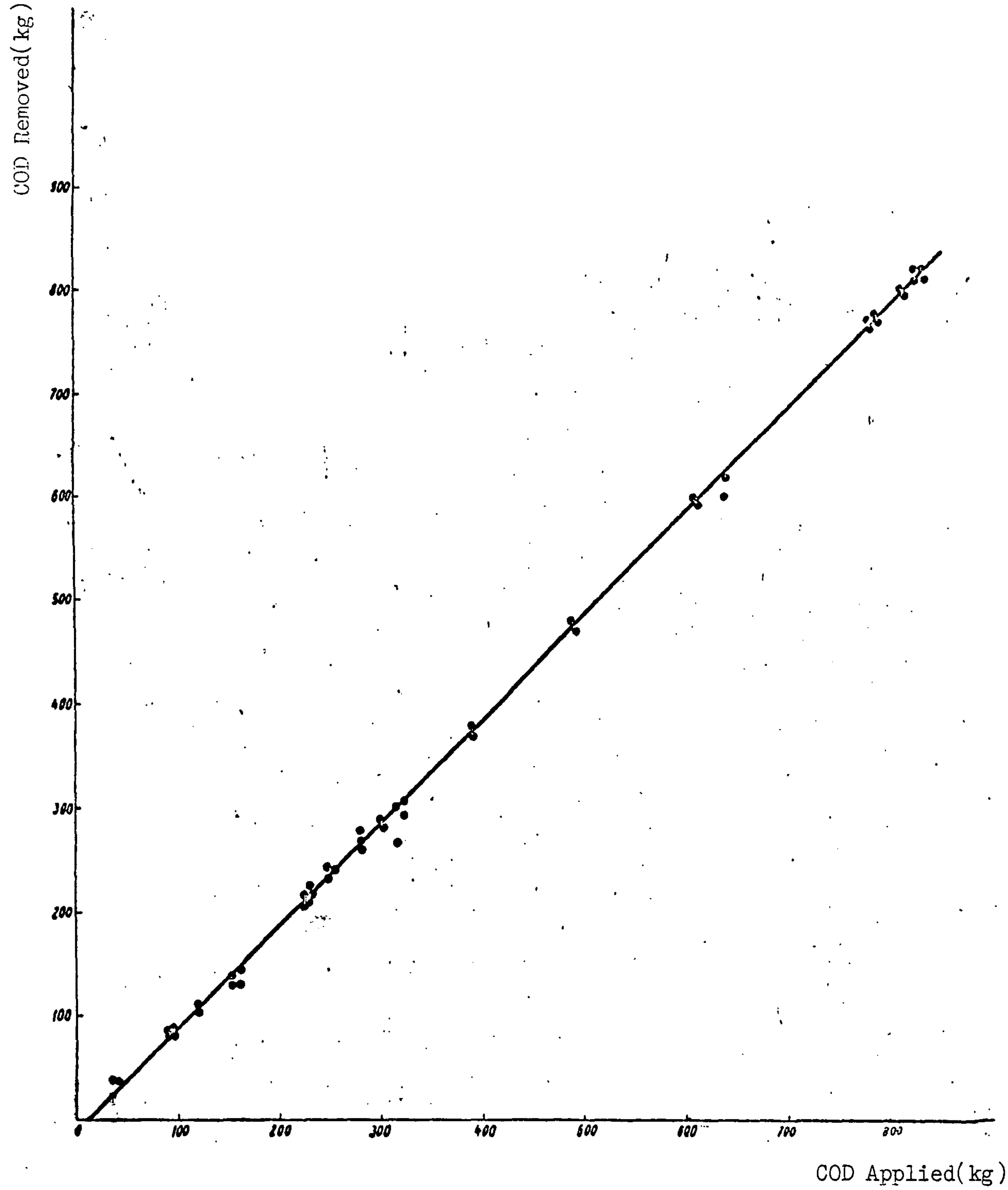


Figure A-31. Relationship between removed and applied monthly COD loading in the case of BLWRS.

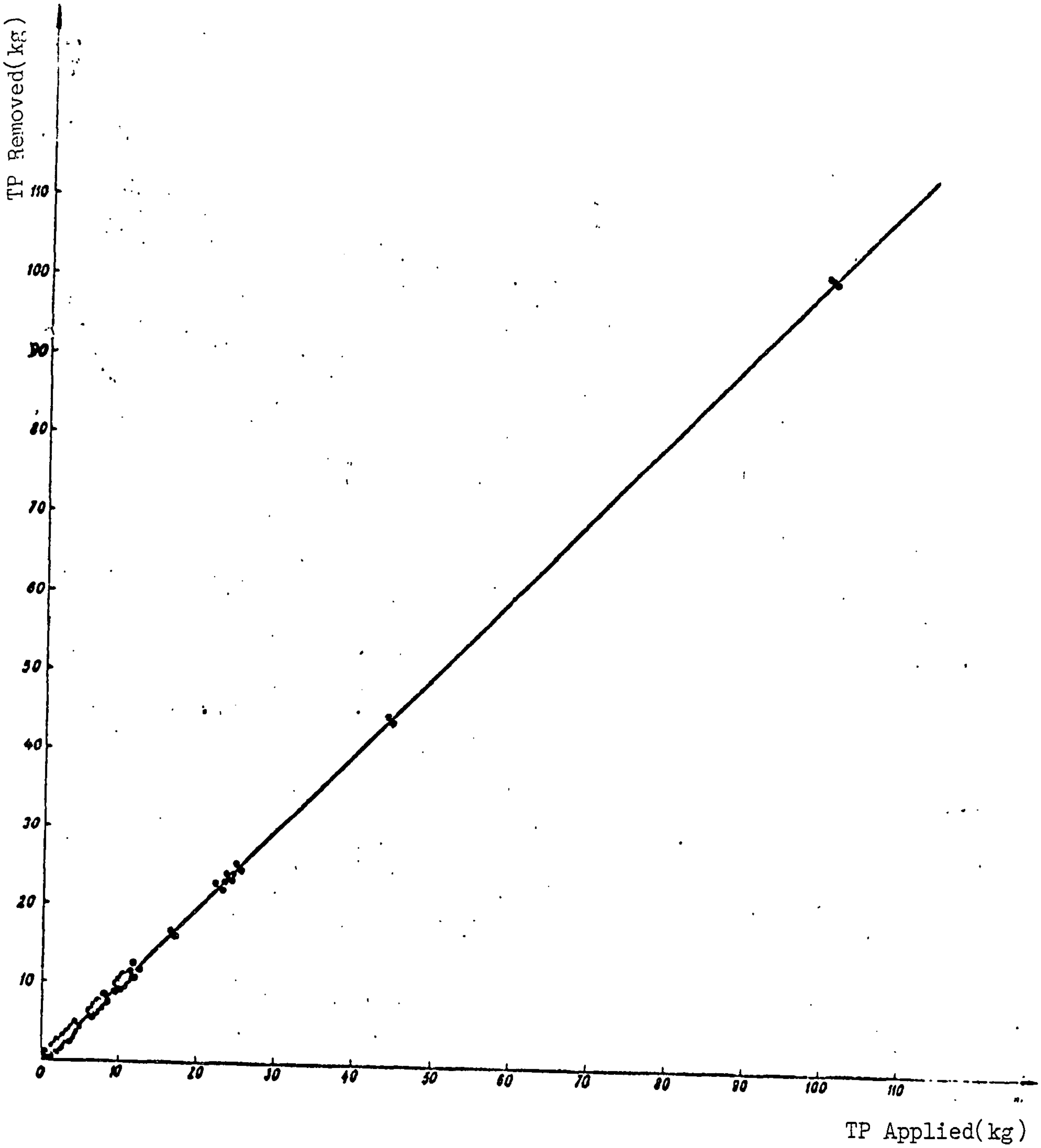


Figure A-32. Relationship between removed and applied monthly TP loading in the case of BLWRS.