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Ammonia, Nitrite and Nitrate Nitrogen Removal From Polluted Source Water With Ozonation and BAC Processes

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Abstract

Studies on the removal of ammonia-, nitrite-, and nitrate nitrogen with ozonation (O_3), sand filtration (SF), biological activated carbon (BAC), SF-BAC, and/or O_3-BAC processes were carried out in two pilot plants and a full scale plant, respectively. The results showed that all of the tested processes exhibited certain nitrogen removal efficiencies, of which both the O_3-SF-BAC and O_3-BAC processes were most effective and efficient in removing ammonia nitrogen, with mean removal efficiencies of some 90 and 80 percent, respectively.

Ozonation was found able to oxidize some organic nitrogen into ammonia, and nitrite ion into nitrate ion. It was also found out, with interest, that the O_3-BAC process can carry the nitrification process to the end under sufficient DO content, as well as more hydrocarbon substrates through ozonation that are more easily assimilated by some strains of nitrobacter that can multiply heterotrophically in its carbon beds. In the BAC process, both the DO and easily assimilated substrate contents were too low in its carbon beds due to no ozonation to sustain nitrobacter growth; but the nitrite conversion bacteria, like nitrosomas, can survive under such conditions. As a result, nitrite or nitrate ion content increased multiply in the effluents from BAC or O_3-BAC processes over their influents, respectively.

The removal mechanisms of various processes for the three forms of nitrogen were studied and discussed, and the optimum design parameters were determined as well.

Introduction

With the rapid development of urban construction and industrial and agricultural economies, more and more municipal, industrial, and agricultural wastewaters carrying a wide variety of pollutants have been discharged into receiving waters, thus causing increasing pollution of many drinking water sources to different extents. Nitrogenous compounds, particularly the ammonia nitrogen as the main form of nitrogen present in wastewaters and in receiving waters, are among the most important pollutants, for they can make the receiving waters, the stable ones like lakes, reservoirs and bays in particular, eutrophic, thereby promoting the overgrowth of algae, accompanied by increases in turbidity, color, odor and taste, and resulting in the deterioration of source water. Therefore, it is imperative to remove ammonia nitrogen and other forms of nitrogenous compounds from polluted source water.

Breakpoint chlorination had been widely used for many years with high ammonia removal efficiency. However, it is very expensive because of high consumptions of chlorine. Moreover, it has been found that this process can cause marked increases in trihalomethane (THM) concentrations and other chlorinated organic compounds. As a result, this technology has been abandoned in many water treatment plants.

In China, the pollution of water sources has been even worse, because the great majority of wastewaters have been discharged directly into receiving waters without any treatment, along with large quantities of runoff from farmlands. These farmlands are treated with excess amounts of chemical fertilizers, resulting in ammonia nitrogen contents as high as 3-5 mg/L in many water sources, with 10 or more in some. Therefore, there is an urgent need to research and develop some new technologies for nitrogen removal with such merits as high removal efficiency, low cost and no seriously hazardous side reactions like those which occur during breakpoint chlorination.

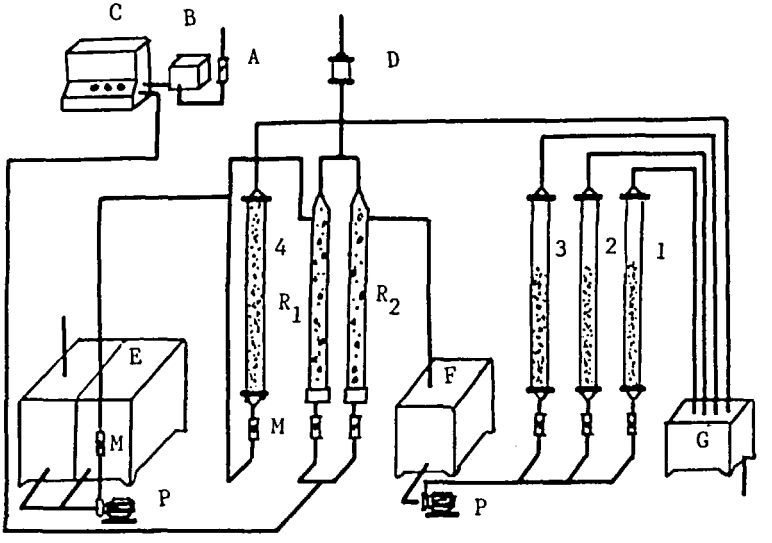
Some unit processes, such as ozonation (O_3), sand filtration (SF), biological activated carbon (BAC), and some treatment processes such as ozonation-sand filtration-biological activated carbon (O_3-SF-BAC), and ozonation-biological activated carbon (O_3-BAC) were studied experimentally in two pilot plants and a full scale plant. Details of the studies are described in the following sections.

Studies in Pilot Plants

EXPERIMENTAL STUDY IN 8 m^3/DAY PILOT PLANT

Equipment: Based on the pollution characteristics of source waters, a pilot plant with a treatment capacity of 8 m^3/day, comprising preozonation, rapid sand filtration, and biological activated carbon units, was designed and installed (see Figure 1). This set of test equipment was used to conduct comparative studies of four different processes, i.e., direct filtration and adsorption through an activated carbon bed (BAC process), preozonation-biological activated carbon process (O_3-BAC), preozonation-

rapid sand filtration process (O_3-SF process), and preozonation-rapid sand filtration-biological activated carbon process (O_3-SF-BAC).



Legend: A - dryer-filter; B - oil-free compressor; C - ozone generator; D - GAC reactor; 1 - activated carbon column; 2-activated carbon/sand column; 3 - sand filtration column; 4-activated carbon column; E -raw water storage and adjusting tanks; F - intermediate storage tank for ozonated water; G-purified water sampling tank; M - rotameter; P - pumps; R_1 and R_2 - ozonation reactor.

Figure 1. Pilot plant comprising preozonation, sand filtration and biological activated carbon units to conduct comparative studies of four different treatment processes.

The operating procedures are as follows: the water to be treated was first stored and adjusted in tank E, from which it was pumped both into the activated carbon column 4 and ozonation reactors R_1 and R_2 simultaneously. In the former case, the water flowed upwards through the activated carbon bed, and then flowed from the top of column 4 into the purified water sampling tank G, thus completing the BAC process. In the latter case, the ozonated water from reactor R_2 flowed into intermediate storage tank F, from which the ozonated water passed through columns 1, 2, and 3 upwards in parallel, which are, respectively, activated carbon column, sand (lower layer)-activated carbon (upper layer) column, and sand filtration column.

The ozone-containing air from the ozone generator was delivered to the diffusers located on the bottoms of R_1 and R_2 at a constant gas flow rate and a constant ozone content (2% by weight), and passed through

R_1 and R_2 upwards in bubble form, and contacted with the water to be treated in countercurrent or cocurrent mode in R_1 and R_2, respectively. The exhaust gas from column R_2 passed through activated carbon reactor D, in which the residual ozone was destroyed on the carbon surface.

Columns 1, 2, 3, and 4 were made of perspex, and measured 2.5 m by 100 mm, while columns R_1 and R_2 were made of glass, with dimensions of 2.5 m in height and 100 mm in diameter. The concentrations of ozone in gas and in solution were determined by the iodometric and OTM methods, respectively.

Several kinds of polluted waters from different sources were used in the experimental study. During low flow periods tap waters were used as raw waters, which did not meet standards for drinking water in some parameters, as well as raw waters from surface and/or ground water sources. In other periods, tap water to which was added a small portion of combined municipal wastewater was used as the raw water.

The pilot plant performed under the operating conditions as shown in Table I.

TABLE I. PILOT PLANT PROCESS PARAMETERS

Ozonation Contact Columns	Adsorber for Residual Ozone
Ozone dosage: 4-5 mg/L	Activated carbon bed
Ozone utilization rate: 80%	D 30 cm, H 30 cm
Liquid/gas ratio: 1.6/1 (v/v)	Packed with GAC of
Contact time: 3-5 minutes	ZJ-15 type
Water flow velocity: 24-30 m/h	
Contact mode:	Sand Filtration Column
Countercurrent in R_1	
Cocurrent in R_2	Grain size: 0.5 - 1.5 mm
Column Material: glass	Bed depth: 1.2 m
Column Dimensions	Bed diameter: 100 mm
L = 2.5 m; D = 100 mm	
Activated Carbon Columns	Dimensions of Columns 1-4
Activated carbon: ZJ-15	L = 2.5 m; D = 100 mm
Grain size: d 1-mm; L 2-3 mm	
Bed depth: 1.20 m	Water Flow Rate in Columns 1-4
Bed diameter: 100 mm	
	7 - 10 m/h
Activated carbon/sand column	
	Filtration time in columns 1-4
Bed depth: 1.2 m	
AC : 0.70 m	7 - 10 min
Sand : 0.50 m	Backwash flow rate, 50-60 m/h
Bed diameter: 100 mm	Bed Expansion: 50-80%
Columns (1-4) material: perspex	Backwash time: 10 - 15 min

Results and Discussion

Our previous studies (1,2) have indicated that activated carbon is hardly able to remove any ammonia nitrogen through physical adsorption. However in this study, the BAC, O_3-SF, and O_3-BAC processes all exhibited marked removal efficiencies for ammonia nitrogen when treating raw waters from either the Songhua River or ground water containing ammonia nitrogen levels in the range of 0.3 to 0.6 mg/L (see Figure 2). It was found from observation of ammonia nitrogen removal variation during the interval between two backwashes that the ammonia nitrogen removal efficiencies were approximately directly related to dissolved oxygen consumption. After backwashing, ammonia nitrogen was removed at very low efficiency, then its removal efficiency increased gradually while DO decreased with operating time. After the next backwash, the ammonia nitrogen removal decreased again by a large margin. Consequently, the ammonia removal efficiency exhibited periodic variation with backwashing frequency.

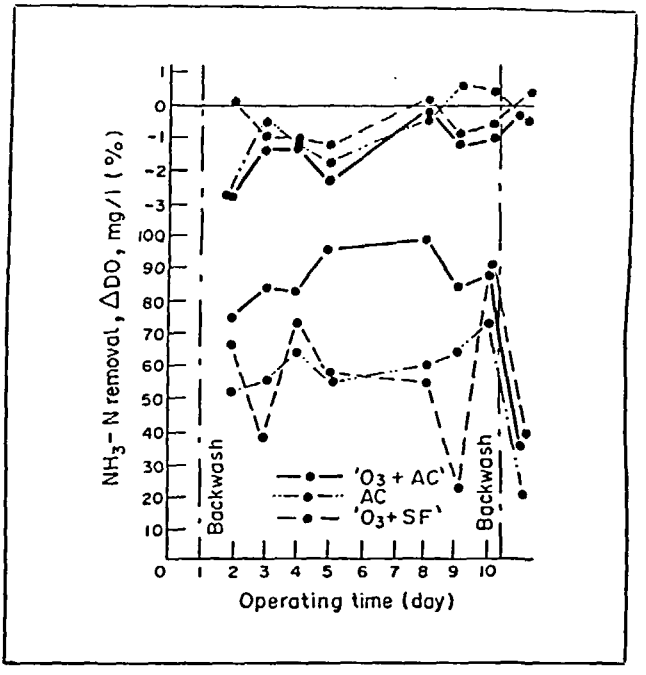


Figure 2. Variation of NH_3-N and DO consumption with time.

The ammonia nitrogen removal efficiency was found to vary with operating time from 52.1 to 73.5% (mean 61.2%) for the BAC process, from 19.6 to 90.6% (mean 52.4%) for the O_3-SF process, and from 75.7 to 98.8% (mean 86.8%) for the O_3-BAC process. The results are comparable to the work of Nastorg and Raplat (3).

In this study, the ammonia nitrogen removal efficiency is considered to be a result of biological activity in both the sand filter and GAC columns. Of the three processes tested, the "O_3-BAC" exhibited the highest removal efficiency due to the most vigorous biological activity, indicated by a large quantity of zooglea found in its GAC bed by microscopic examination and the highest bacteria count found in its effluent (10^4-10^5 MPN/mL). The zooglea and protozoa species and population, as well as the bacteria count in the effluents from the GAC bed in the BAC process and from the sand filtration bed in the "O_3-SF" process were found to be much lower than with the "O_3-BAC" process, only 10^2-10^4 MPN/mL. Correspondingly, their removal efficiencies for ammonia nitrogen removal were much lower than that of the "O_3-BAC" process.

While the ammonia nitrogen was greatly or markedly removed by the "O_3-BAC" process, or for the "O_2-SF" or "BAC" processes, concentrations of nitrite and nitrate ions increased only slightly under the specific experimental conditions. It can be concluded from the findings that the majority of ammonia nitrogen removed was assimilated by bacteria for synthesis of new bacterial cells, while the remaining portion was converted into nitrite and nitrate ions through nitrification under aerobic conditions.

EXPERIMENTAL STUDY IN A 500 L/D SMALL PLANT

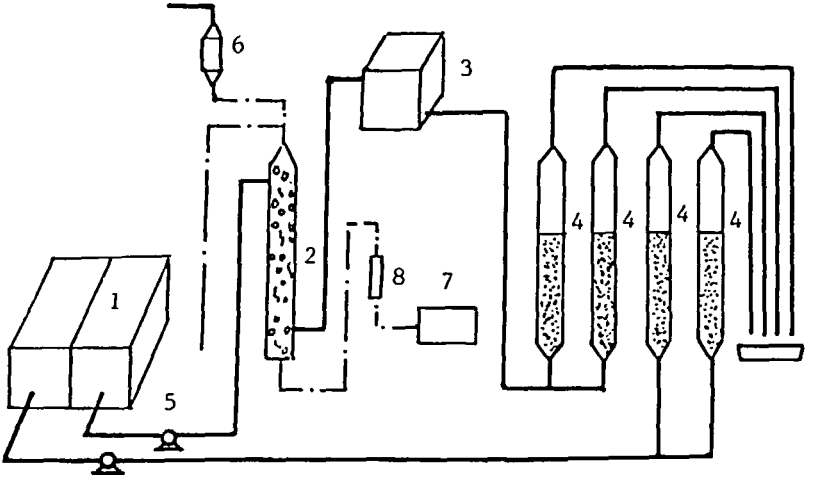
A further study on the removal of ammonia, nitrite and nitrate nitrogen was carried out in a small plant with ozonation and biological activated carbon processes, as shown in Figure 3. The results showed that the ammonia nitrogen content in water increased to some extent after ozonation at doses of 2-4 mg/L (see Figure 4). This probably is due to conversion of some nitrogenous organic compounds into ammonia by ozonation.

Ammonia nitrogen was removed at rather high efficiencies either in the "O_3-BAC" or "BAC" processes. Moreover, the "O_3-BAC" process again was found to be more effective in removing ammonia nitrogen compared with the "BAC" process (Figure 5).

With respect to nitrite ion removal, it was found that the "O_3-BAC" process exhibited quite high removal efficiency, whereas the "BAC" process showed negative nitrite ion removal efficiency (Figures 6 and 7). In other words, the nitrite nitrogen content of the effluent was markedly higher over that of the influent. The difference between the two processes is assumed to lie mainly in dissolved oxygen content and easily assimilated substrates in the activated carbon beds, both of which increase during ozonation.

In the "O_3-BAC" process, sufficient oxygen content and abundant easily assimilated hydrocarbon substrates in the carbon bed promoted the growth both of nitrosomas and nitrobacter, thus carrying the nitrification process through to the end, while in the "BAC" process, the dissolved oxygen content was too low and the content of simple hydrocarbon substrates that can be assimilated by some strains of nitrobacter was too insufficient, because of no ozonation to sustain growth of nitrobacter.

However, the nitrosomas was found to be able to grow under such circumstances. As a result, the nitrification microbial community was dominated by the nitrite conversion bacterial species; consequently the ammonia nitrified only to nitrite ion instead of nitrate ion, thus causing a remarkable increase in nitrite ion content in the effluent over that in the influent.



Legend: 1 - raw water tank; 2 - ozonation reaction column; 3- intermediate high level water tank; 4 - activated carbon columns; made of glass, 2.4 cm diameter x 1.5 m height; columns I and III packed with activated carbon X-11, 60 cm in depth; columns II and IV packed with activated carbon ZJ-15, 90 cm in depth; 5- pumps; 6 - activated carbon adsorber for residual ozone; 7- ozone generator; 8 - rotameter.

Figure 3. Small plant including ozonation and BAC unit processes.

Conclusion

All of the four tested processes exhibited different nitrogen removal efficiencies, of which both the ozonation-sand filtration-activated carbon adsorption (O_3-SF-BAC) and ozonation-activated carbon (O_3-BAC) processes were most effective due to vigorous biological activity in carbon beds, particularly biological assimilation, i.e., conversion of ammonia nitrogen into protoplasm through synthesis of new cells and complete nitrification. Without sufficient oxygen and simple hydrocarbon substrates that could be easily assimilated by some heterotrophic species of nitrobacter as in the "BAC" process. Without ozonation, the carbon bed was not able to carry the nitrification through to the end, resulting in a remarkable increase in nitrite content in its effluent over the influent.

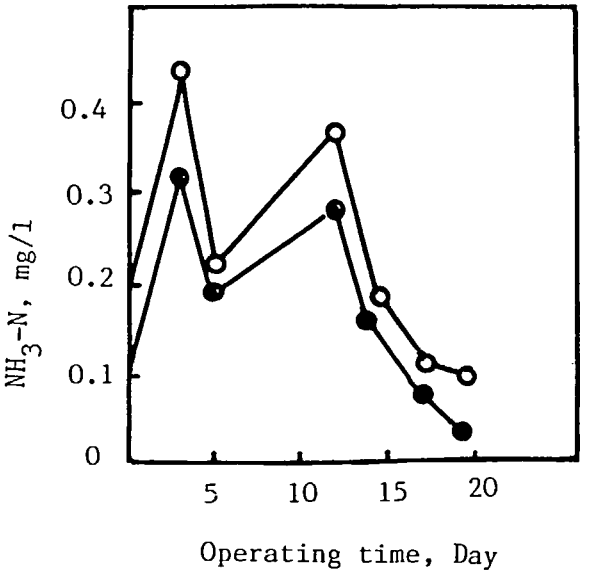


Figure 4. NH_3-N content curves for raw water (lower) and ozonated water (upper).

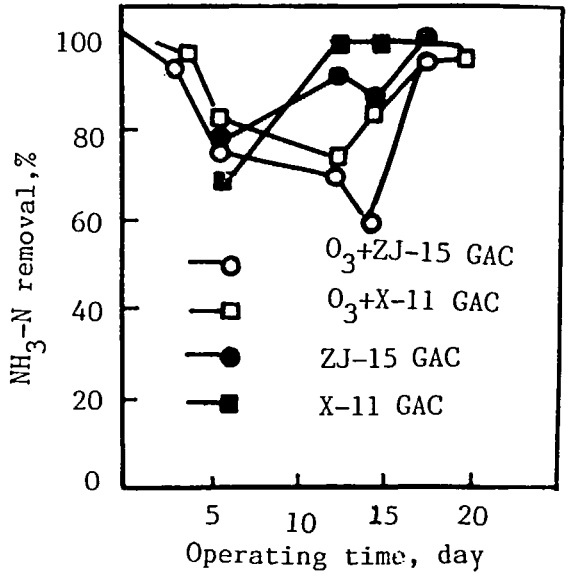


Figure 5. NH_3-N removal curves for "O_3-BAC" and "BAC" processes.

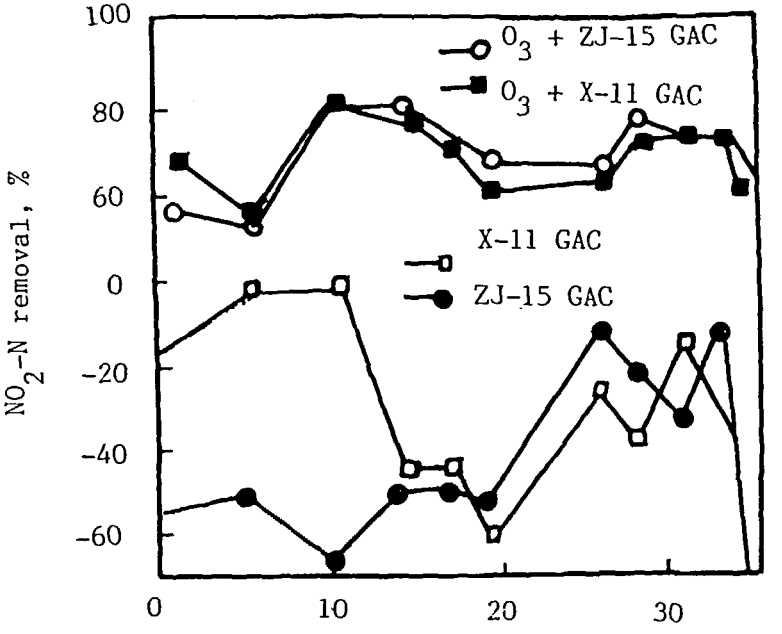


Figure 6. Nitrite nitrogen removal curves for "O_3-BAC" and "BAC" processes.

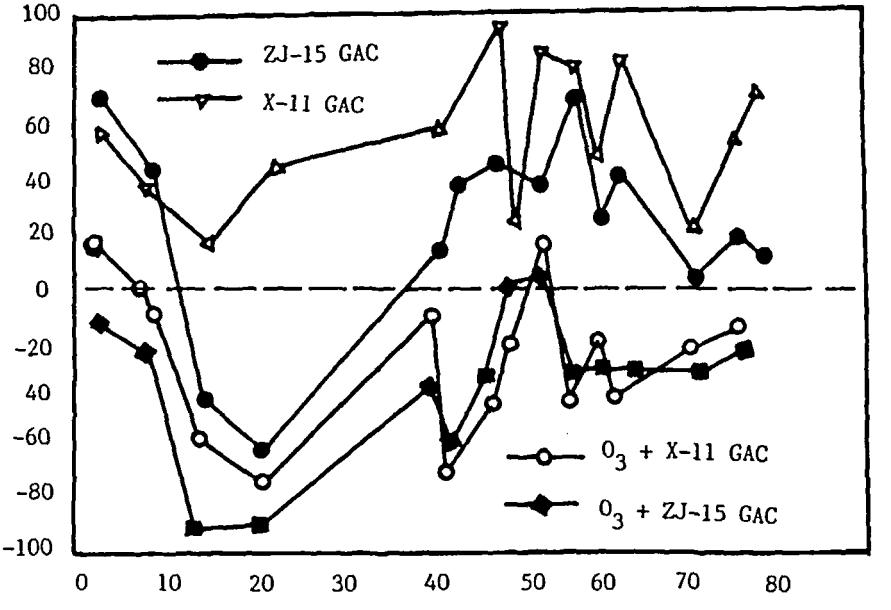


Figure 7. Nitrate nitrogen removal curves for the "O_3-BAC" and "BAC" processes.

Studies In A Full Scale Plant

EQUIPMENT

The plant with a throughput capacity of 500 m^3/d was designed by us according to the data obtained from pilot plant tests, set up and put into trial operation at the Songjiang Cannery in Harbin in 1983. Besides the usual accessory equipment, such as a raw water holding tank, water tower, pumps and measuring devices, it consists mainly of two pressurized dual media microflocculation/direct filtration (MF/DF) columns and two pressurized GAC adsorption columns. A photograph of the plant process, and a schematic diagram of the plant process are shown in Figures 8 and 9, respectively.

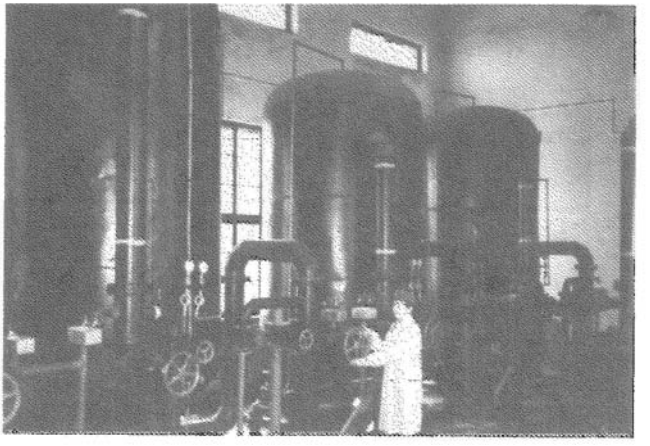
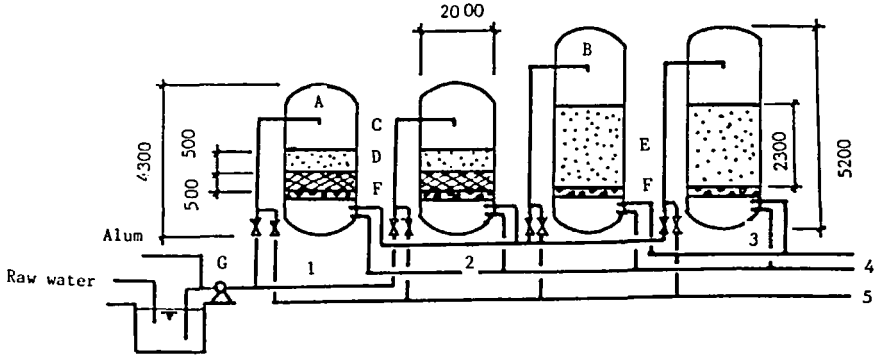


Figure 8. Photograph of the water treatment plant set up in Songjiang Cannery, Harbin, China.

OPERATION

The raw water was first sent from the sump to the two MF/DF columns in parallel by a pump operating at a pressure of 3 kg/cm^3. The coagulant, 5% $Al_3(SO_4)_3$ solution, was injected into the suction pipe of the pump and mixed vigorously with raw water when flowing through the turbine of the pump. The coagulant dosage was maintained in the range of 3-5 Al_2O^3/L. When the mixed water flowed from the top downward through the domes of the MF/DF columns, i.e., the upper section of the columns above the bed surface, with a retention time of some 10 minutes, hardly visible and finely dispersed microflocs formed, which then were removed efficiently in the filtration bed through various mechanisms, such as adherence of microflocs to the surface of filter media, and aggregation into larger flocs in the gaps among the filter media granules. As a result, the great majority of turbidity was removed, color, COD_m, iron, manganese, and copper also were removed efficiently in the filtration

bed to different extents. In addition, ammonia and nitrite ions were partially removed, due to biological activity in the beds.



Legend: A - dual medium filtration column; B - biological GAC column; C - anthracite bed, 0.6 m deep, grain size 1.2-1.8 mm diameter; D - quartz sand bed, 0.5 m deep, sand grain size 1.0-1.5 mm diameter; E - granular activated carbon, type ZJ-15; F - supporting layer of coarse sand; G - pump; 1 - raw water pipe; 2 - connecting pipe between outlets of DF columns and inlets of GAC columns; 3 - connecting pipe between outlets of GAC columns and water tower; 4 - inlet pipe of backwashing water; 5 - outlet pipe of backwashed water.

All the columns are made of carbon steel of 10 mm thickness. Their inner walls are lined with epoxy coating, in order to protect the columns from corrosion. The MF/DF columns are 2-m in diameter and 4.3-m in height, packed with 1.1-m deep dual medium filtration bed, i.e., 0.6-m deep granular anthracite (grain size 1.2-1.8 mm) bed above and 0.5-m deep quartz sand bed (grain size 1.0-1.5 mm) below.

Figure 9. Schematic diagram of the water treatment plant set up in the Songjiang Cannery, Harbin, China.

Having flowed out of the bottom of the MF/DF columns, the pretreated water further flowed through the connecting pipe, 2, to the top of the BAC columns, and then filtered downward through the GAC beds with a retention time of some 15 minutes. Thus a wide variety of pollutants were removed through various mechanisms, such as filtration, adsorption, and biological assimilation.

During the trial test run, the plant had operated continuously, and the MF/DF columns were backwashed once each day, while the BAC columns were backwashed every two or three days.

The major dimensions and parameters of the MF/DF and BAC columns, and their operating results are shown in Tables II and III, respectively.

TABLE II. MAJOR DIMENSIONS AND PARAMETERS OF MF/DF AND BAC COLUMNS

Pressurized MF/DF Columns	Pressurized BAC Columns
D 2000	D 2000
H 4300	H 5200
Bed, upper layer:	GAC beds:
anthracite, h_1 600	h_1 2000
d 1.2-1.8	carbon type ZJ-15
	carbon size
lower layer:	d 1 and L 2.5
quartz sand, h_2 500	
d 1.0-1.5	supporting layer:
supporting layer:	coarse sand
coarse sand, h_3 300	h 300
d 1.5-2.0	d 1.5-2.0
filtering velocity: 7-10 m/h	filtering velocity: 7-10 m/h
contact time: 8-11 min	contact time: 12-17 min
backwash rate: 40 m/h	backwash rate: 40 m/h

Results and Discussion

It has been shown in our earlier study (1) that ammonia nitrogen cannot be removed from water by activated carbon adsorption because of its high solubility and polarity in water, which prevent ammonium ions from being adsorbed by activated carbon. However, during the trial operation period, ammonia nitrogen was removed remarkably well (see Figure 10) in both MF/DF and GAC columns, of which the prepositioned MF/DF columns were responsible for a major portion of total ammonia removal, with a mean removal efficiency of 72% vs 83% in total.

The considerably high removal efficiencies achieved in the contact microflocculation/filtration columns can be ascribed to both the coagulation and biological activity. In the coagulation/flocculation process, the ammonia ions can be removed through their formation of colloidal particles as potential or counter ions, and further coagulating into insoluble and settleable flocs, which can be removed readily when the water flows through the beds.

The biological activity in both the dual media filtration beds and GAC beds was identified through microscopic observation, by means of which numbers of zooglea, protozoa, vorticella, rotaria, etc., were found in the backwash waters from both kinds of beds, which usually serve as indicator organisms of vigorous biological activity under aerobic conditions.

TABLE III. ANALYTICAL RESULTS OF WATER SAMPLES FROM THE WATER TREATMENT PLANT OF THE SONGJIANG CANNERY, HARBIN

Parameters	Raw Water Influent (mg/L)		Effluent, MF/DF Beds (mg/L)		(%)	Effluent, BAC Beds (mg/L)		Total
	Range	Mean	Range	Mean	Removal	Range	Mean	Removal (%)
Color*	10 - 47	24	3 - 25	14	41.7	0 - 15	7.8	67.5
Turbidity*	65 - 480	181	4 - 105	23	87.3	0 - 8	4.0	97.8
COD_m	3.37-10.87	6.56	1.02-7.04	3.56	45.7	1.02-4.49	2.32	64.6
Phenol	0.001-0.04	0.003	—	—	—	ND-0.001	0.001	80
Cyanide	ND-0.008	0.003	—	—	—	ND-0.001	0.001	65
Fluoride	0.06-6.00	1.82	0.006-1.50	0.38	70.1	0.006-0.50	0.18	90.1
DBS	ND-0.28	0.04	—	—	—	ND-0.07	0.01	97.5
Ammonia-N	0.56-7.3	0.99	0.06-3.2	0.28	71.4	ND-1.90	0.17	82.8
Nitrite-N	ND-0.31	0.03	ND-0.05	0.11	62.3	ND-0.01	0.004	86.7
Nitrate-N	0.06-1.02	0.47	—	—	—	0.05-0.92	0.43	8.5
Iron	0.31-2.6	0.80	0.06-0.46	0.15	81.3	ND-0.35	0.08	90.0
Manganese	0.01-0.62	0.30	0.01-0.30	0.11	63.3	ND-0.16	0.06	80.0
Copper	0.09-1.18	0.53	0.03-0.34	0.13	75.5	ND-0.17	0.04	92.5
Hardness	29.7-61.5	36.0	21.7-49.9	37.6	-4.3	31.4-43.3	35.5	1.5
pH*	7.1 - 8.0	7.5	6.5 - 7.6	7.1	---	6.5 - 7.5	7.2	---

* These parameters are expressed in their respective units, not in mg/L.

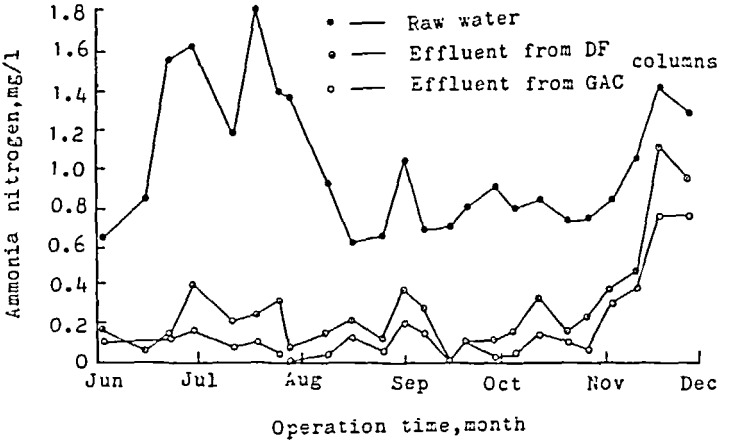


Figure 10. Evolution of nitrogen ammonia in DF and GAC columns.

Nitrite nitrogen also was removed efficiently in both the dual media and GAC beds. The removal was dominated by biological activity, which is indicated by the trend of an increase in nitrite ion removal efficiency with operating time. In the dual media filter beds, for instance, whereas hardly any nitrite nitrogen was removed during the initial operating period of some two months, since then its removal efficiency has increased sharply (see Figure 11).

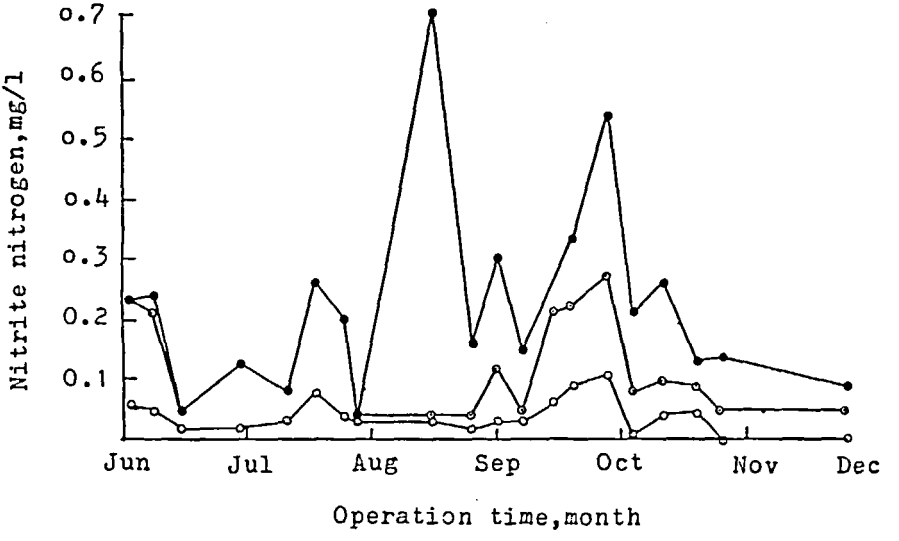


Figure 11. Evolution of nitrite nitrogen in dual media and GAC beds.

By contrast, nitrate nitrogen was removed negligibly, sometime with negative removal efficiencies, due to nitrification taking place in GAC beds. The average nitrate nitrogen removal efficiency of GAC beds was only 8.5% in the trial operating study (see Figures 12 and 13).

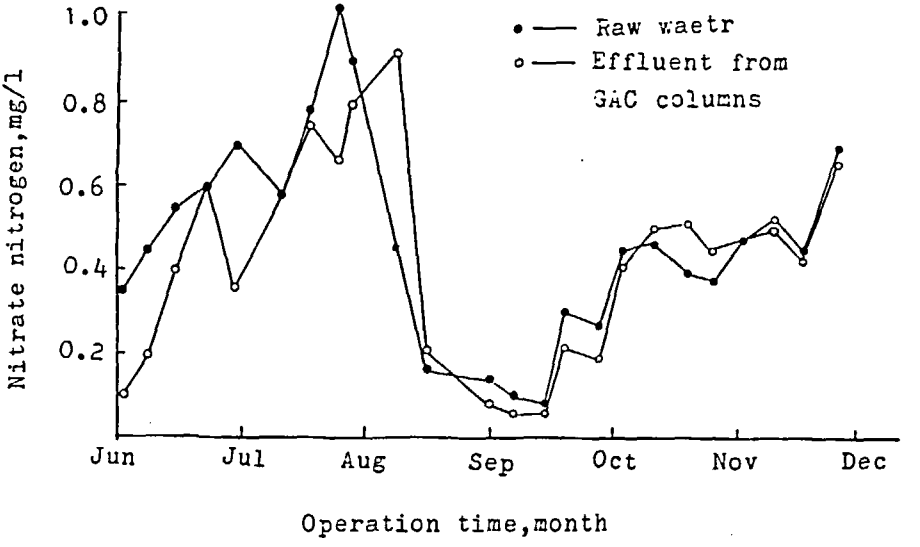


Figure 12. Evolution of nitrate nitrogen through GAC columns.

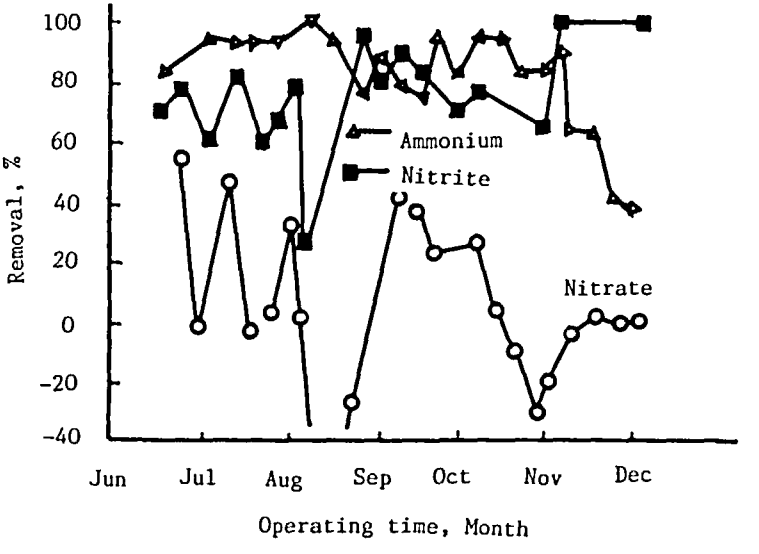


Figure 13. Removal efficiencies for NH_3-N, NO_2-N, and NO_3-N.

It should be noted that the nitrification accompanied by the increase in nitrate content in the final effluent over that in the raw water had occurred just after backwashing, due to sufficient oxygen present in GAC beds available for the process. In this case, however, the increase in nitrate nitrogen was a far cry from the absolute value of the decrease in ammonia nitrogen levels (see Table IV), which is different from other findings (5). This means that under the specific conditions, the ammonia and nitrite ion removed in both the dual media and GAC beds primarily had been converted into protoplasm of new bacterial cells through biological assimilation, flocs, and nitrogen gas, N_2, through anaerobic processes in the GAC beds, particularly in the deeper layers of the beds during the later operating period before backwashing.

TABLE IV. CHANGE OF NH_3-N OR NO_3-N LEVELS IN GAC BED EFFLUENTS COMPARED WITH INFLUENTS

Test	NH_3N Decrease (mg/L)	NO_3N Increase (mg/L)
1	0.15	0.01
2	0.12	0.10
3	0.17	0.08
4	0.17	0.09
5	0.16	0.01

Our earlier study (4) has indicated that under aerobic conditions maintained by supplying adequate oxygen to GAC beds through ozonation or aeration, much higher nitrate concentrations in final effluents over influent concentrations can be achieved, due to more intensive nitrification. Unfortunately, this situation is undesirable, since high nitrate concentrations in drinking water poses potential hazards to human health, particularly to infants in terms of blood disease.

In order to prevent a marked increase in nitrate ion content in the final purified water, it is desirable that the water treatment plant use an aerobic/anoxic operating process, i.e., the prepositioned and postpositioned treatment steps, such as the MF/DF and BAC columns in this case, perform with or without aeration, respectively, so that the nitrification/-denitrification can take place during the water treatment process.

The conversion of ammonia nitrogen into the various forms of nitrogen can be described as shown in Figure 14.

Conclusions

The most interesting findings in this study is that the plant exhibits much higher removal efficiencies for nitrite and nitrate ions under non-aeration conditions than those usually achieved under aeration or ozonation conditions. This can be attributed to the aerobic nitrification, followed by anoxic denitrification, and/or synthesis of protoplasm of new cells with ammonia. nitrite or nitrate ions as nitrogen sources in biological assimilation processes.

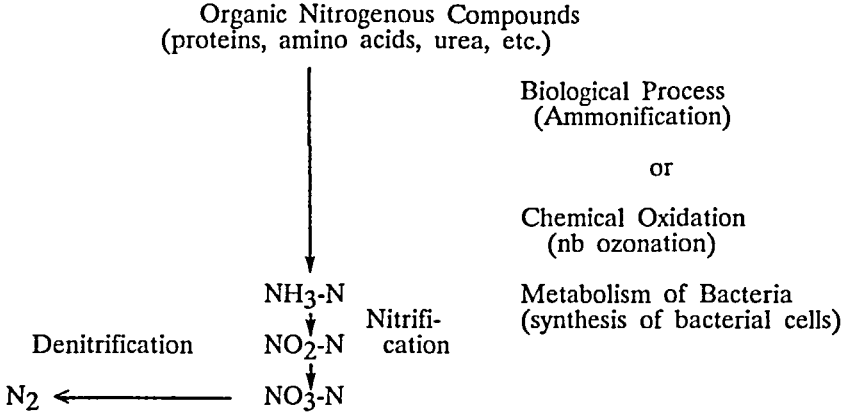


Figure 14. Conversion of ammonia nitrogen into various forms of nitrogen.

References

1. WANG, B.; LIU, X., 1982, "The Efficiencies and Mechanisms of Removing Pollutants From Water With Activated Carbon", The Chemistry and Chemical Industry of Forest Products 1:1-14 (in Chinese).
2. WANG, B.; TIAN, J., 1981, "Experimental Studies on the Purification of Polluted Groundwater in Harbin With New Techniques" (in Chinese).
3. NASTORG, J.C.; RAPLAT, M., 1981, "Ozonation Étagée et Traitement Biologique", Tech. & Sci. Municipales 5:309.
4. WANG, B.; YIN, J.; TIAN, J.; FAN, Q.; LIU, R.; HUANG, J., 1985, "Purification of Polluted Source Water With Ozonation and Biological Activated Carbon Processes", Ozone: Science & Engineering. 6(4):261-273.
5. SONTHEIMER, H.; HEILKER, E.; JEKEL, M.R.; NOLTE, H.; VOLLMER, F.H., 1978, "The Mülheim Process", J. Am. Water Works Assoc. 70(7):393-396.
6. SONTHEIMER, H., 1978, "Biological Treatment of Surface Water in Activated Carbon Filters", Ozone News 5(7), Part 2 (July issue).

Key Words

Ozone, Ammonia, Nitrite Ion, Nitrate Ion, Biological Activated Carbon, Sand Filtration, Microflocculation/Direct Filtration, Drinking Water Treatment, Ozone Promotion of Biological Activity, Assimilation of Nitrogen Into Bacterial Cells

Résumé

La séparation de NH_3-N, NO_2-N et NO_3-N de l'eau polluée par ozonation (O_3), filtration sur sable (FS), charbon actif biologique (CAB), ozonation filtration sur sable (O_3-FS), ozonation-filtration sur sable-charbon actif biologique (O_3-FS-CAB) et charbon actif biologique (CAB) a été étudiée dans deux installations pilote et use station d'épuration des eaux de petites dimensions (500 m^3/jour) quoique complète.

Les résultats ainsi obtenus ont montré que, parmi les procédés testés, "O_3-CAB" et "O_3-FS-CAB" sont les plus efficaces dans l'élimination de NH_3-N, NO_2-N, et NO_3-N. Les efficacités d'élimination (en valeurs moyennes) des NH_3-N sont 80% et 90% respectivement. Les mécanismes d'élimination des NH_3-N, NO_2-N, et NO_3-N par ce procédé sont également discutés.

Zusammenfassung

Die Untersuchungen über Entfernung von Ammonium, Nitrit und Nitrat durch Ozonierung (O_3-Prozess), Sandfiltration (SF), biologische Aktiv-Kohle (BAC), SF-BAC, and/or O_3-BAC Prozesse wurde ausgeführ in zweien Pilotanlage und einen industriellen Anlage. Die Ergebnise zeigen dass alle Prozesse ergab different Eliminationeffekt von Ammonium, Nitrit, und Nitrat, besonders beide Prozesse "O_3-BAC" und "O_3-SF-BAC" sehr effektiv Ammonium, Nitrit und Nitrat entfernen, mit durchschnitliche NH_3-N von 90 oder 80 prozent, respektiv. Verschiedene Mechanismen der Elimination von Ammonium, Nitrit, und Nitrat mit den Ozonierung, "BAC" und "O_3-BAC" Prozessen wurde festgestellt.