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第9回日独排水及びスラッジ処理についてのワークショップ会議録

PROCEEDINGS OF THE 9TH JAPANESE-GERMAN WORKSHOP ON WASTE WATER AND SLUDGE TREATMENT

平成16年1月27日～30日
つくば・国土技術政策総合研究所

January 27-30, 2004
International Conference Room,
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure and Transport, Japan
Tsukuba, Japan

国土交通省　国土技術政策総合研究所
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure and Transport, Japan

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国土交通省　国土技術政策総合研究所　下水道研究部
独立行政法人　土木研究所　リサイクルチーム／水質チーム

PROCEEDINGS OF THE 9TH JAPANESE-GERMAN WORKSHOP ON WASTE WATER AND SLUDGE TREATMENT

Water Quality Control Department,
National Institute for Land and Infrastructure Management
Ministry of Land, Infrastructure and Transport, Japan

Recycling Research Team & Water Quality Research Team,
Incorporated Administrative Agency
Public Works Research Institute

概要

この報告書は、平成16年1月27日～30日につくば・国土技術政策総合研究所で行われた「第9回日独排水及びスラッジ処理についてのワークショップ」における議事録及び講演資料等を取りまとめたものである。同ワークショップでは、日独の政府・自治体・研究機関の代表者により、下水道技術に関する両国の現状と課題について発表と意見交換が行われた。

キーワード: 下水道技術、流域管理、二国間協力

Synopsis

This publication contains the proceedings of the 9th Japanese-German Workshop on Waste Water and Sludge Treatment, which was held at National Institute for Land and Infrastructure Management, Tsukuba, during 27-30 January 2004. In this Workshop, current status and subjects of wastewater control were presented and discussed by government and municipal officials and researchers of Japan and Germany.

Key Words: Wastewater Control, Watershed Management, Bilateral Cooperative Research

序　文

「日独排水及びスラッジ処理のワークショップ」は，1974年10月に日独政府間で締結された「科学技術分野における協力に関する日本国政府とドイツ連邦共和国政府との間の協定」に基づく環境保護パネルにおいて開催が合意されたものである。1976年6月に設置された「日独環境保護技術パネル」の第4回会合の席上でドイツ側より、下水道技術について専門家による情報交換を深めるためのワークショップの開催が提案された。この提案を受けて準備が進められ、1982年10月に建設省土木研究所（当時）で日独ワークショップの第1回会議が開催された。以降、2〜3年毎にドイツと日本で交互に開催されている。

今回の第9回日独ワークショップは、2004年1月27日から1月30日までつくば市，東京都，京都府及び滋賀県で開催され，日本側委員団は、国及び政令市からの参加者を含め合計20名が，ドイツ側からはドイツ連邦教育科学研究技術省のHeidborn研究部長をはじめとする10名が参加した。

論文発表及び全体討議は，27日，28日の両日にわたって国土技術政策総合研究所にて行われ、「下水道行政」、「規制と評価」、「化学物質の管理」、「流域における水システム」、「下水処理技術」、「下水汚泥の有効利用」の6セッションにおいて、対策が必要となっている課題や最新技術について，日本側は10論文、ドイツ側は9論文の発表が行われた。29日から30日にかけては、東京都下水道局の芝浦処理場・有明処理場・海水浄化プラント、京都市下水道局の鳥羽処理場、滋賀県琵琶湖環境部の市街地排水浄化対策事業施設の現地調査を行った。また，ワークショップの最後には共同コミュニケが作成され，ワークショップが両国の研究活動に役立ってきたこと，さらにこれを継続していくことが重要であることを確認し，次回のワークショップがドイツで開催することが合意された。

今回の会議で得られた知見や情報は，我が国の下水道技術者にとって有益なものと思われる。本報告書は，このような考えに基づき，ワークショップにおける発表論文と討議の内容を取りまとめたものである。報告書の冒頭にあたり，各委員及び関係各位に深く感謝するとともに，本報告書が我が国の下水道分野で活用され，下水道技術の発展に寄与することを希望する次第である。

平成16年3月

第9回日独排水及びスラッジ処理についてのワークショップ

日本側委員団　団長　宮原　茂

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１．共同コミュニケ

Joint Communique
9th Japanese - German Workshop
on Waste Water and Sludge Treatment

National Institute of Land and Infrastructure Management,
Tsukuba, January 27-28, 2004

1. As an activity within the Japanese - German cooperation in the field of environmental protection technology, the 9th Workshop on Waste Water and Sludge Treatment was held on January 27-28, 2004 in National Institute of Land and Infrastructure Management(NILIM), Tsukuba, Japan.

2. The Japanese delegation was headed by Mr. Miyahara, Director, Water Quality Control Department, NILIM, Ministry of Land, Infrastructure and Transport (MLIT), and was composed of one delegate from MLIT, seven delegates from NILIM, five delegates from Public Works Research Institute (PWRI), one delegate from Osaka Sangyo University, three delegates from Japan Sewage Works Agency (JSWA), one delegate from National Institute of Public Health, Ministry of Health, Labor and Welfare, one delegate from Tokyo Metropolitan Government and one delegate from Kyoto City.

3. The German delegation was headed by Dr. Heidborn, Head, Division of Regional Environmental Research, Federal Ministry of Education and Research (BMBF), and was composed of one delegate from BMBF, one delegate from Darmstadt University of Technology, one delegate from Technical University Braunschweig, two delegates from Research Center Karlsruhe, one delegate from Berlin Water, one delegate from Water Technology Center Karlsruhe, one delegate from University of Witten/Herdecke, one delegate from Consultant Engineers Ltd and one delegate from RWTH Aachen University.

4. Opening addresses were given by Mr. Hamaguchi, Director General of NILIM, Mr. Miyahara and Dr. Heidborn.

5. The Chairmanship was shared by Dr. Takahashi, MLIT, Dr. Heidborn, Prof. Sugawara, Osaka Sangyo University, Dr. Furrer Research Center Karlsruhe, Mr. Fuhrmann, Research Center Karlsruhe, Dr. Tanaka, PWRI and Mr. Sakai, JSWA.

6. In total 10 papers were presented from the Japanese delegation and the German delegation

presented nine papers. The topics were wastewater administration, regulation and evaluation, management of chemicals, water systems in watershed, wastewater treatment technology and beneficial use of wastewater sludge.

7. A study tour was made on January 29 to Shibaura Wastewater Treatment Plant (WTP), Ariake WTP and a sea water purification plant in Ariake area in the Tokyo Metropolitan Government. Another study tour was made on January 30 to Toba WTP in Kyoto City and a pollution control facility for non-point source in Shiga Prefecture.

8. Both sides agreed that this kind of research and development was very worthwhile. The 10th workshop is proposed to be held in Germany in the year 2006.

9. Both sides agreed to discuss the possibility of joint research projects on the following mutual interests:

- chemicals in water cycle
- economical and ecological optimization of wastewater systems including energy and material recovery
- water reuse including MBR
- watershed management

Heidborn 28/1/04

宮原茂

Shigeru Miyahara	Juergen Heidborn
Head	Head
Japanese Delegation	German Delegation

共同コミュニケ
第9回日独排水及びスラッジ処理についてのワークショップ

於　国土技術政策総合研究所（つくば）
2004年1月27～28日

1. 第9回日独排水及びスラッジ処理についてのワークショップは，環境保護技術分野における日独協力の一環として，2004年1月27日から28日まで，つくば市の国土技術政策総合研究所で開催された。

2. 日本側代表団は，国土交通省国土技術政策総合研究所の宮原下水道研究部長を団長として，国土交通省1名，国土技術政策総合研究所7名，（独）土木研究所5名，大阪産業大学1名，日本下水道事業団3名，厚生労働省国立保健医療科学院1名，東京都下水道局1名，京都市下水道局1名で構成された。

3. ドイツ側代表団は，ドイツ連邦教育科学研究技術省（BMBF）地域環境研究部長のHeidborn（ハイドボーン）博士を団長として，BMBFから1名，ダームシュタット工科大学1名，ブラウンシュバイク工科大学1名，カールスルーエ研究所2名，ベルリンウォーター1名，カールスルーエ水技術センター1名，ヴィッテン/ヘルデッケ大学1名，コンサルタントエンジニア社1名，アーヘン工科大学1名で構成された。

4. 開会式では，国土技術政策総合研究所の浜口所長，宮原下水道研究部長とBMBFのハイドボーン博士の挨拶があった。

5. 議長は高橋博士、ハイドボーン博士，菅原教授，フラー博士，フアマン氏，田中博士，酒井氏が務めた。

6. 日本側から10編，ドイツ側から9編の論文が発表された。議題は，「下水道行政」，「規制と評価」，「化学物質の管理」，「流域における水システム」，「下水処理技術」と「下水汚泥の有効利用」であった。

7. 1月29日に東京都の芝浦処理場，有明処理場及び有明エリアの海水浄化プラントの現地調査，1月30日に京都市の鳥羽処理場，滋賀県の市街地排水浄化対策事業の現地調査が行われた。

8. 両国代表団は，この種の研究開発が非常に価値あるものであることについて合意した。また、第10回のワークショップを2006年にドイツで開催することが提案された。

9. 両国代表団は，下記の相互の関心事項について共同研究の可能性を検討することに合意した。

・水循環中の化学物質
・エネルギー及び物質の回収を含む経済的，環境的に最適な下水道システム
・膜分離活性汚泥法を含む水の再利用
・流域管理

日本代表団	ドイツ代表団
団長　宮原　茂	団長　Juergen Heidboen

２．会議の概要

１月２７日

２．１　開会

日本側を代表して浜口国土技術政策総合研究所長から、ドイツ側代表団を歓迎するとともに、本会議において有意義な成果が得られることを期待する旨の挨拶があった。

生態系の保全や流域管理の視点など下水道に求められる役割が拡大していること、政策決定や効果的な事業実施のために，これまで以上の研究活動、技術開発が求められていることが述べられた。

また、旧土木研究所が再編成され国土技術政策総合研究所（国総研）と独立行政法人土木研究所（土研）の二つの研究機関となったが、協調して下水道関係の研究・技術開発に取り組んでいることが紹介された。

続いて国総研の宮原下水道研究部長から、日独ワークショップが始まった 1982 年当時に比べ，日本における下水道普及率が飛躍的に向上し、その発展には本ワークショップによる技術の導入などが貢献しているが、最近では下水道整備の進展に伴い、汚泥の再利用、病原性微生物や環境ホルモンの問題が課題となっていることが述べられた。

また、前回ドレスデンでのワークショップ後、日本においてはクリプトスポリジウムの制御ガイドラインがまとまるなど日本の下水道技術に関する話題紹介があり、最後に本会議において有意義な成果がもたらされることを期待している旨の挨拶があった。

ドイツ側の代表としてドイツ連邦教育科学研究技術省の Heidborn 博士から、本会議の主催に当たった日本側関係者に謝意が示された。またドイツにおいては水の再利用、関係３省庁によるりんの再利用プロジェクトが進められており、国際河川を持つドイツでは流域単位の統合管理に関心が高まっていることが示された。

更にヨハネスブルグ環境宣言における水問題に関する取り組みにはドイツの提案が大きく関与しており、これからは議論だけでなく技術開発の成果の実行が必要であるとの考えが示され、特にドイツでは開発途上国への技術支援に取り組んでいることなどが紹介された。

２．２　下水道行政

１）日本側発表

国土交通省下水道部の藤木流域管理官より「下水道事業における流域管理」と題し、日本における流域管理の事例として，窒素りんの負荷量割り当てを行った東京湾流総計画、都市再生プロジェクトとして取り組まれている東京湾再生事業及び東京湾流域をモデルに行った排出権取引システムの検討事例の報告が行われた。

２）ドイツ側発表

続いてWitten/Herdecke 大学のRudolph教授より「組織の構造，費用，料金」と題して、ドイツにおける下水道事業の事業主体、環境基準、排水規制など下水道関係法令や排水課徴金制度などに関して、EU環境政策との関わりや連邦政府と自治体の役割分担などについて、他の欧米諸国や日本との比較を交えた報告が行われた。

３）議論

日本側よりドイツの下水道事業が取り入れている「全原価回収の原則」(Full Cost Recovery Principal)における国の補助金など財政支援制度について質問があり、それに対し初期投資に対する補助金は課徴金を原資としたもの以外はほとんど無いとの回答があった。また、集められた排出課徴金の大部分は、実態として汚水処理をはじめとする水環境・水資源の保全のために充当されているが、制度上使途を限定したものではないとの回答があった。

引き続き日本側より、ドイツでは自治体間で下水道料金に格差が生じているかとの質問があり、ドイツ側からは各都市で料金計算手法が異なることや、財政状況に応じて 25～30%程度の料金格差が生じているとの回答があった。

また、ドイツの民間下水道企業の動向に関する質問に対しては、ドイツでは 6,000 を越える下水道施設があるが、多くは数百人規模の小規模な下水道施設が多いため民間側が積極的に参画するような機運は少ないようだとの回答があった。

ドイツ側からは、日本が排出権取引のために使用した負荷量算定シミュレーションモデルがどのくらい統合化されたモデルなのか質問があったが、今回使用したモデルを含め水管理に関係す

る省庁毎に異なったモデルがあり、これについては統合化を進める動きが出てきたとの回答があった。

最後に日本側より日独両方の発表者に対し、ノンポイント汚染に関する経済的アプローチについて質問が出たのに対して、日本側、ドイツ側ともに排出権取引、排水課徴金のどちらも適用できるとの回答があった。

ただし、基本となるノンポイント負荷量の見積もり、対策手法及びモニタリング体制の確保が実際には難しいなどとの発言があった。またドイツでは排出権取引よりも、政策的・制度的に実行できる排水課徴金システムの方が良いと政治家などは広く考えているようだとの発言があった。

２．３　規制と評価

１）日本側発表

国総研下水道研究室の吉田研究官より「ディスポーザー使用による下水道システムへの影響」と題し、国土交通省・北海道・歌登町が 2000 年から 2004 年にかけて実施しているディスポーザー導入社会実験について発表が行われた。ディスポーザー排水の BOD 負荷量は 11.3g/人日であったことや、ディスポーザー導入後にごみ排出量の減少があったことや管渠内に貝殻等の堆積物が確認されたとの報告があった。

２）ドイツ側発表

Karlsruhe 研究所の Furmann 氏より「EU の第 6 次調査研究枠組みプログラム(2002-2006)」について発表があり、ライフサイエンス、情報技術、ナノテクノロジー、航空宇宙、食品安全、持続可能な発展、市民社会の形成等の 7 分野の研究開発に対して、2002 年から 2006 年までに総額 175 億ユーロが支出されるとの説明があった。

３）議論

ドイツ側からドイツの処理場では窒素除去能力が限界だが、COD 処理能力に余裕があるので、ディスポーザー導入は施設の有効利用と考えられるとのコメントがあった。

また、ディスポーザー導入後の管渠の清掃頻度や汚泥量の変化など，ディスポーザー排水の影響について質問があり、管内堆積物はあるが清掃を行う必要があるほどの堆積は認められない、

ディスポーザー普及率の増加に伴い汚泥量の増加が見られると，発表者より回答があった。

日本側からはEUの研究計画と構成各国の研究計画の関係について質問があった。それに対し，各国の研究計画はEU研究計画から独立しているが、加盟国研究予算の約５％はEUの研究計画に振り分けられており、今後はEU研究計画に関する研究予算の占める割合が徐々に増えていくのではないかとの見通しが示された。

また，EUにおける飲料水の安全性に関する研究開発の現状に関して質問があり、南欧、東欧などの飲料水の基準や現状が悪いため、将来的には他のEU諸国の水質基準レベルにまで改善することが課題である等の回答があった。

２．４　化学物質の管理（１）

１）日本側発表

土木研究所水質チームの岡安研究員より「日本の下水におけるエストロゲン様物質の存在状況」と題し、日本国内の下水処理場において遊離態および抱合体のエストロゲン濃度及びノニルフェノール（NP）とその関連物質の実態調査を実施した結果について発表があった。

遊離態エストロゲンは下水処理で効率的に除去されていたものの、エストロゲン抱合体の多くは増加しているようであったとの報告があった。また、NPおよび長鎖のノニルフェノールエトキシレートは減少したが、短鎖のノニルフェキシ酢酸は生成されていたとの報告があった。

続いて土木研究所リサイクルチームの南山主任研究員より「下水汚泥コンポストに含まれる内分泌かく乱物質の、施肥後の消長」と題し、土壌に施用された後の下水汚泥コンポスト中の内分泌攪乱物質の消長について報告があった。

土壌中と浸出液中のノニルフェノール（NP）と17β-エストラジオール（E2）について、初期段階の浸出水では、高濃度のNPとE2が検出されたが急速に減少したとの報告があった。また、土壌中のNPとE2の減少量が、浸出水中のNPとE2に比べて大きかったため、土壌中で物理化学的、もしくは生物学的な分解があると考えられるとの報告があった。

２）ドイツ側発表

Berlin Waterworks の Heinzmann 氏より「ベルリン市の水循環における微量物質の存在状況と挙動及び飲料水との関連性」と題し、表流水の水量に対し下水道から放流される高度処理水の占める割合が大きく、また，帯水層が浅いため汚染リスクが高いベルリンの水利用システムに関する報告があった。

ベルリンの水道水源は土壌浸透と人工的な地下水涵養に依存しているが、いくつかの微量化学物質は、土壌浸透の間に効率的に除去されることが確認されているとの報告があった。また排水処理は膜分離活性汚泥法により微量化学物質の除去性能は若干良いこと、吸着、膜ろ過およびオゾン酸化などが下水処理場で導入されているとの説明があった。

現在、微量化学物質が水生生物や土壌生物に与える影響を研究するため、ベルリンにおける将来の水管理を踏まえた大規模研究プログラム（NASRI）が始動しており、化学的及び微生物学的な観点から、地下水源などの水質に関する研究が実施され、その研究成果は既存の施設の最適な運転や、世界中の新設の施設の設計に反映することを目的としているとの説明があった。

3）議論

下水処理工程でエストロゲン抱合体が増加する理由について質問があり、採取試料の代表性、分析方法の課題及びエストロゲン抱合体前駆物質の存在の3点が関連するとの考えが示された。しかし、下水管渠内の流下過程で変化し遊離態として下水処理場に流入してくると考えられているエストロゲン抱合体が下水処理後にも存在が確認されたことは、新たな知見であると認識された。

ドイツ側から下水汚泥中の NP 関連物質（NPEO や NPEC）の分析法を確立することが目下の課題であり具体的な情報を取るまでに至っていないとの現状が説明された。

これに対し日本側では湖沼の底泥中の NP 関連物質、エストロゲンの測定結果を例に述べた上で分析方法の正確さを追求する一方で、実態の情報収集も必要であるとのコメントがあった。

また、ヒトや水生生物に対する内分泌攪乱物質による影響の評価方法に関する議論では、オスの魚類中に発現する特定のタンパク質（ビテロジェニン）を用いる方法、イングランドで確認されている水生生物の生殖器官の異常の出現頻度、および個体数の変化が考えられるのではないかとの説明があった。

ドイツ側からはベルリンの水利用システムに関しては、下水処理放流水が水域を経由して飲料水として取水されるまでに要する時間は表流水での滞留時間を含めて約 3 ヶ月程度であるとの説明があった。また、市街地排水などのノンポイントソースからの微量化学物質汚染については、それぞれの発生源の評価、物質収支に基づいた解析が必要であるとの認識が示された。

２．５　化学物質の管理（２）

１）日本側発表

国立保健医療科学院水道工学部部長の国包章一博士より「水道水中の化学物質の管理」と題し、規制緩和、地方分権、情報公開の必要性など最近の日本の政策動向の説明があり、従前の水道水質基準に関するレビューと 2004 年 4 月施行の新しい水道水質基準について発表があった。

水道水中における化学物質への対応に関しては、これまでの良質の水道水源の選定と水質保護という観点に加え、水質変化に対応した水処理施設の操作管理と、水道施設内における水質悪化の防止の観点が大変重要であると提起された。

その上で、具体的な施策としての水質基準・水質モニタリング、水源保護・浄水技術の開発、浄水施設の運転・維持管理の三要素と、それらの相互関係や連動性を重視した水道事業の運営・管理のあり方について説明が加えられた。

水道水中の化学物質の由来について、水道水源（70％以下）、浄水処理プロセス用試薬（10％以下）、給水用資材（10％以下）及びサービス設備用資材の４種類に分類した上で、水質リスクを評価した新しい水質基準の特徴と、それに対応した水質調査など水道水質管理の動向に関する報告があった。

２）ドイツ側発表

Water Technology Center Karlsruhe に所属する Mueller 博士からは「ドイツにおける浄水技術の現状」と題し、ドイツにおける上水道システムや水質ガイドラインの紹介と、河岸帯ろ過(Bank filtration)、微粒子除去、吸着と酸化、消毒など上水処理技術の利用状況や効果に関する発表があった。

ドイツの上水道は地下水と河岸帯ろ過が水道取水量全体の約７割であること、飲用水の６割が消毒なしで供給されていることなど土壌ろ過の機能・効果に関する発表と、水質基準は配水シス

テムでのリスク特性から、農薬のように濃度的増加が生じ難いものと、トリハロメタンのように濃度的増加が生じ易いものとに分けて、規制基準と対策を講じているとの説明があった。

また、ドイツの水道関係者においては微量有害化学物質とクリプトスポリジウムなど病原性微生物に対する関心が特に高く、その対策としては，紫外線照射、膜ろ過、活性炭吸着などの処理技術が主要であり、その効果に関する実測結果の報告があった。

3）議論

ドイツ側から日本の水道水中病原性微生物の測定方法に関し質問があり、日本では全ての水道事業者に塩素消毒が推奨されているため、代替管理手法として送配水施設入り口での濁度により管理がされていることが説明された。

また、これまでは一般細菌と大腸菌群を測定していたが、今回の水質基準の改定により大腸菌群を基準項目から除外し、代わりに大腸菌を新たに追加したことと，大腸菌指標の場合、計測の値は大腸菌群に比べて小さくなるが、その意味は大きいとのコメントも加えられた。

また，塩素消毒のみで送配水を行っている小規模浄水処理施設が数多く日本には存在するため、全ての上水処理場にろ過を義務付ける議論も始まったが、水源によって病原菌による安全リスクが異なることや、コストの問題から方策は検討中との説明があった。

これに対し、ドイツでも消毒のみの小規模浄水処理場が多く、どのような処理工程を設けるべきか議論しており、ろ過処理工程を導入する際の優先順位を付ける技術、膜ろ過も含めて効果的・経済的な処理技術の開発・応用などについて、日独両国間における今後の技術交流への期待が示された。

また、日本側発表者から病原性微生物の対応策として、従来のろ過方式のほかに、紫外線照射が有効であること、日本国内では孔径2μm程度のＭＦ膜が開発されているとの紹介があった。

日本側から日本の水道水質の現状と消毒についてドイツ側のコメントを求めたところ、ドイツでも河川表流水を水源としている場合には消毒を行っているとのコメントがあった。

しかし、日本のように蛇口で残留有効塩素濃度を確保することについては、有機物の分解性の把握や処理システムの最適化などにより、なるべく低レベルにした方が良いとの見解を示した。ドイツでは、水道利用者が塩素臭に大変敏感で、些細と思われても不満が殺到するので、水道事

業体は塩素管理に特に注意を払っているとのことであった。

日本側の残留塩素と一般細菌指標との関係性についての質問に対し，発表者から塩素・生物易分解性有機物・微生物の3者間の相互依存・制約関係について回答があった。

また、抗生物質など医薬関連物質に関する水道分野におけるドイツでの対応については、これらの物質に関する関心は高まっているものの、どの水質関連セクターに対処責任があるのかなど、具体的な役割分担やガイドラインは定まっていないとのことであった。

抗生物質など医薬関連物質に対する規制や制御については、今後、きちんとした対応が求められる問題であることが、日独関係者の共通認識として確認された。

1月28日

2．6　流域における水システム

1）日本側発表

国総研下水処理研究室の斎野研究官から「下水処理水中の衛生学的指標の消長」と題して、模型水路を用いた各指標細菌（大腸菌、大腸菌群、および一般細菌）の衛生学的指標としての妥当性を検討した結果について報告があった。

調査の結果からは、水温や塩素中和の影響を受けること、大腸菌以外の指標細菌は流下過程で減少率が低下することから再増殖している可能性があること等が示された。

2）ドイツ側発表

Karlsruhe 研究所の Furrer 博士から、「連邦教育科学技術省プログラム：分散型の（代替的）水システム」について発表が行われ、開発途上国において安全な飲料水を確保するための方策として検討されている既存の分散型処理施設の組み合わせや改良技術について、各国で実施されている調査事例やドイツ国内での実証試験が報告された。

3）議論

ドイツ側の過去の調査では，ふん便性大腸菌群の消長は海水の塩分濃度による影響を受けるようだとのコメントがあったが、日本側は河川における検討であり、今後海域への放流については

参考としたいとの回答があった。

また、ドイツ側からは消毒の目標としてより強力な消毒を目指すのか、あるいは海水との混合など水域での消長に期待するのかという質問があったが、今後の対策については、今回の調査結果を踏まえた上で検討することとしていると日本側からは回答があった。

日本側から、途上国では下水処理水や汚泥の再利用に関するリスク管理は先進国とは異なると考えるが、どのように考えているか質問があり、ドイツ側は未処理下水の農業利用などについて今後検討する予定であるとの回答があった。

ドイツにおける途上国援助のプロジェクト選定方法に関する質問に対しては要請主義であるとの回答があった。

日本側から発表中に説明のあった「分散処理」の定義と、し尿分離トイレや真空式トイレなども検討しているのか確認があり、ドイツ側から伝統的な下水道システムは排除しており、ビルなどの閉鎖循環システムなどは概念に含まれていること、し尿分離トイレなども含めドイツ国内の２カ所で分散システムを実施しているとの回答があった。

また、日本側から分散型の導入は新規建設のみか、既存ビルの更新時などもあるのか質問があり、ドイツ側からは集中から分散への変更など更新時も考慮しており、現にキャンプ地などで提案しているとの説明があった。

分散型を推進する背景としては、技術の進歩により小さな処理槽がコントロール可能となったという技術的理由と、整備対象に小エリアが増えて従来型下水道ではコストがかかりすぎるという経済的理由によるとの説明があった。

２．７　下水処理技術（１）

１）日本側発表

日本下水道事業団技術開発部の村上総括主任研究員より「都市下水処理における膜分離活性汚泥法の特性」と題して MBR（膜分離活性汚泥法）の都市下水処理への適用に関して、ろ過性に影響する活性汚泥性状と汚泥中の有機物の関係、MBR における汚泥発生量の検討、MBR 処理水を再利用する場合の処理水質の特性について、実験プラントによる検討結果が紹介された。

2）ドイツ側発表

Darmstadt 工科大学の Cornel 教授から「欧州における膜分離活性汚泥法の現状」と題して欧州の MBR の現状が紹介された。現在、30 以上の都市下水処理用 MBR と 120 以上の産業排水処理用 MBR が稼動しているが、膜面洗浄用曝気等によるエネルギー消費が 1 ～1.5kWh／m^3 と多いのが課題であると発表があった。

Aachen 工科大学 Montag 研究員より「公共下水処理場におけるりん回収」と題し、下水からのりん回収技術に関し、Aachen 工科大学で実施中の PRISA プロジェクトが紹介された。

本プロジェクトでは、りんを MAP により回収しているが、下水中のりんの 40～50％が回収出来、産業用途や農業用途に利用可能であり、この方法はフォストリップ・晶析法よりも経済的であるとの説明がされた。

3）議論

日本側のＭＢＲの汚泥発生量は少なかったとの発表に対し、ドイツ側からプロセス中での重金属の挙動を確認しているのか質問があり、日本側からは時間経過により汚泥中金属量は次第に増加した後、ほぼ一定となったなどの回答があった。

これに対し、ドイツ側から.余剰汚泥の発生が無いということは、重金属や内分泌撹乱物質等の除去が出来ていないと考えられること、汚泥発生量の低減効果と汚泥を引き抜いて別途処理する方式と比較して、どちらがコスト的に有利か慎重な検討が必要とのコメントがあった。

日本側からは、産業排水処理用と都市下水処理用では、寿命が違うと考えられるが、都市下水処理用膜の寿命をどのように見積もるべきかという質問があった。

これに対し、毛髪等の付着が原因となって、４～５年で膜モジュールを交換した事例がドイツにはあるが、膜の耐用年数はまだ不確定要素であること、産業排水用 MBR については、２年間あるいはそれ以下で交換することがあるとの回答があった。

また、MBR は、活性汚泥と膜による固液分離の組み合わせであり、RO 膜であれば色まで除去できるが、MF 膜では色や塩類の除去は期待出来ないとのドイツ側からコメントがあった。

りん回収技術に関しては、日本側より回収されたりん中の有機物や重金属等の不純物の含有量の程度と不純物の除去方法に関して質問があったのに対し、発表者からは実験開始直後であり、不純物に関するデータは無いとの回答があった。

ベルリン市の事例では、下水からアンモニアとりんを MAP として回収しているが、回収された MAP 中の重金属は、ドイツの汚泥再利用に関する農業利用ガイドライン値を下回っていること、栄養塩類の含有量は肥料の原料として使用できるほど高いとの追加コメントがあった。

２．８　下水処理技術（２）

１）日本側発表

東京都下水道局の北村氏より、「国際水協会（IWA）活性汚泥モデルの革新」と題して、東京都において効率的な窒素・りん除去を目的に開発した IWA 活性汚泥モデルを基に構築した運転管理システムソフトに関する発表が行われた。

ソフトウェア開発の目標は、①日本語操作ができること、②現場技術者が活性汚泥モデルに関して予備知識が無くても操作できること、③日常測定データで利用できること、④市販のパソコンで利用できることであり、シミュレーション結果やソフトウェアの画面などが紹介された。

２）ドイツ側発表

Consultant Engineers 社の Scheer 主任研究員から「統合システムのオンラインシミュレーションと最適化－下水処理場と管路システム－」と題して、下水処理場と下水管渠の統合システムのオンラインシミュレーションについて発表が行われた。

化学物質汚染対策、維持管理、設備建設の各段階でコスト削減を目的としており、人口 15 万人規模の下水道について、下水処理場の曝気効率及びポンプ稼働率の最適化、管渠計画において雨水貯留タンクのサイズ、位置及び貯留操作の最適化シミュレーションの適用事例が紹介された。

特に夜間時の対応、雨天時の対応、アンモニアの流出問題および長期的影響などに対応すべく現在研究中であることの報告がなされた。

３）議論

ドイツ側から、有機物指標として東京都ソフトウェアで採用されている CODMn と IWA 活性汚泥モデルの構成要素である CODCr との相関について質問があり、東京都から、CODMn から CODCr へ

の換算係数は3.0としてモデルシミュレーションを行なっているとの回答があった。 また、ドイツ側からソフトウェアの開発コストや開発元についての質問があり、東京都から、民間2社との共同開発であるとの回答がなされた。

日本側から、データベースおよび通信回線への質問、また、下水管渠に設置されたセンサーの長期的応答性についてについての質問があった。これに対してドイツ側から、吸光度により正確な数値を求めているとの回答がなされた。

2．9　下水汚泥の有効利用

1）日本側発表

日本下水道事業団技術開発部の山本研究員より「下水汚泥の炭化システムと炭化製品の特性」と題して、下水汚泥炭化について、現在操業中のプラントのシステム、炭化製品の物理化学的性質、シクラメンの栽培実験等の有効利用に関する実験、製品の安全性に関する説明が行われた。

続いて京都市下水道局の稲波係長より「京都市での溶融結晶炉による汚泥有効利用」と題して、京都市における下水汚泥の結晶化スラグについて、溶融方式、スラグの物理化学的性質、有効利用の用途および使用状況等に関する説明があった。

2）ドイツ側発表

Braunschweig 工科大学の Dichtl 教授より「汚泥分解による費用最小化―実規模での比較」と題して、溶解遠心分離やオゾン処理等を用いた汚泥分解の実規模実験を行い、汚泥量、消化ガス発生量やコスト等について総合的に経済効果を評価した結果に関する報告があった。

3）議論

ドイツ側より、炭化製品の水銀含有量に関連して排ガス中の水銀濃度、炭化製品中のりんの形態と溶出速度の関係、焼却と比較した場合のメリットについて質問があり、日本側より、排ガス中の水銀濃度は日本の基準以下であること、窒素が溶出しないことに比べてりんの溶出速度は速いが、りんがアルミニウムや鉄と結合していてpHが通常の場合にはりんは溶出しにくいこと、小規模では炭化炉にコスト面でメリットがあると回答された。

ドイツ側から、運転上の問題点や溶融炉の今後の設置見込みについて質問があり、日本側より、点検修理等のために連続運転はおよそ2-3ヶ月となっており、年平均の稼働率は50～60％であること、近年、溶融炉の設置は下火であるが、コンクリート骨材、路盤材としての基準化が進めば傾向が変わる可能性もあることが回答された。

日本側から、オゾン処理は嫌気性消化の前処理と汚泥の減量化のどちらが目的であるのか、また、2005年に埋立処分が全面禁止されることに関連して、現状では何％が埋立処分されているのかについて質問があった。これに対してドイツ側から、嫌気性消化の前処理が目的であること、また、10年前には埋立処分が50%であったが、現在は15%ほどになっているとの回答がなされた。

２．１０　閉会

出席者全員の参加のもとHeidborn博士の司会により閉会式が行われ、次回の開催予定や今後の共同研究に関するコミュニケの確認が行われ、今後も本ワークショップは継続することが確認され、次回は2006年にドイツで開催されることになった。

また、水利用に関する化学物質問題、省エネ・リサイクルなど経済的で環境に配慮した下水処理システム、水の再利用、流域管理に関する共同研究プロジェクトの実施について検討することとした。

３．現地調査の概要

１月２９日と１月３０日の２日間、ドイツ連邦教育科学研究技術省のHeidborn博士を始めとするドイツ側代表団一行は、東京都、京都市及び滋賀県の下水道関連施設を訪問した。

初日の１月２９日は東京都の芝浦処理場、有明処理場及び有明処理場に設置されている海水浄化プラントとその対象水域であるお台場海浜公園を訪問した。

芝浦処理場では、合流式下水道の改善対策と再生水供給システム等について調査を行った。

合流改善対策としては、1,000m/日のろ過速度を有する高速ろ過施設と、消毒効率が高い臭素系薬剤を用いた雨天時下水のための消毒施設を調査した。また、光ファイバーを用いて無人ポンプ場を処理場から遠隔制御するシステムや、レーダーによる降雨把握についても調査した。

ドイツ側から、リアルタイムコントロールの導入の予定について質問があったが、今後導入が期待されるとの回答がなされた。さらに、設計処理水量4,300m^3/日の再生水を近隣の都市再開発地域に供給するための施設（砂ろ過、生物膜、オゾン処理及び膜処理）を見学した。

続いて、有明処理場では、高度処理、再生水供給、ヒートポンプによる熱回収及び施設上部の積極的な複合利用等の技術について調査を行った。処理施設の大部分は地下にあり、地上にある管理棟、高度処理棟についても、その上部は温水プール、体育館、下水道関連の博物館など都市施設として活用されているものであった。

最後に、都市の水辺空間であるお台場海浜公園を対象とした海水処理実験について調査を行った。海水浄化プラントは有明処理場内に設置されており、処理場近くの海水を取水して浄化し、処理水はお台場海浜公園に放流されている。

春から秋にかけて約200日間、5,000m^3/日の水量をろ過と紫外線消毒により処理する施設であった。また、お台場海浜公園内の浄化区域は、外からのオイルボールの流入を防ぎ、処理水の外への拡散を防止するためのフェンスによって仕切られている。現地調査の当日は、海水浄化プラントは運転されていなかったが、プラント装置とお台場海浜公園の状況を確認した。

二日目の１月３０日は京都市の鳥羽処理場及び滋賀県の市街地排水浄化施設を訪問した。

京都市の鳥羽処理場は、分流一部合流の排除方式をとり、西日本で最大規模の処理能力を誇る処理場であり、汚泥の発生量も多いため有効利用の観点から溶融石材化を行い建設資材として活用している。

結晶化スラグは、耐酸性や強度に優れた石材として有効に活用されるが、ドイツ側は、結晶化スラ

グでできている透水性ブロックの品質に関心を示した。また、現地において透水性に関する実験が行われ、それも視察した。

続いて、水質汚濁が著しい琵琶湖南湖の水質改善を目的として市街地排水を処理する滋賀県の山寺川市街地排水浄化対策事業施設を訪問した。本施設は雨天時に市街地（80ha）から雨水幹線を通して流出する下水（1降雨あたりの浄化対象水量：7,200m^3）を処理し、晴天時には伯母川の河川水を一定量処理する施設である。

処理方法は接触酸化及び植生浄化により行われるが、冬季は植生浄化の代わりに土壌浄化による処理がなされていた。本施設は散歩道沿いに設置してあるため、啓発効果も大きく、植生浄化施設の維持管理は地域ボランティアが実施しているとのことであった。ドイツ側は、土壌浄化施設における水の流れや維持管理の方法等に関心を示していた。

４．別添参考資料

別添１　ワークショップ記者発表資料

平成１６年１月２２日（木）
(独)土木研究所リサイクルチーム
上席研究員　　鈴木　穣
連絡先　　029-879-6764（直通）

日本とドイツとの下水道技術に関する国際会議が開催される

―「第９回日独排水及びスラッジ処理についてのワークショップ」の開催―

国土交通省では、海外との下水道技術の交流を深めるため、各種の国際会議、技術者相互派遣、共同研究、海外調査、技術援助等について積極的に取り組んでいる。特に、今回１月２７日からつくば市の国土技術政策総合研究所において、「第９回日独排水及びスラッジ処理についてのワークショップ」（以下、日独ワークショップという。）を開催し、情報交換及び活発な議論を行う予定である。

１．経緯

昭和４９年１０月に締結された「日独科学技術協力協定」に基づき、昭和５１年６月に「日独環境保護技術パネル」が設置された。このパネルの第４回会合の席上でドイツ側より、下水道技術について専門家による情報交換を深めるためのワークショップの開催が提案された。

この提案を受けて準備が進められ、昭和５７年１０月に建設省土木研究所（当時）で日独ワークショップの第１回会議が開催された。以降、概ね２年毎にドイツと日本で交互に開催されている。

２．第９回日独ワークショップの概要

第９回日独ワークショップは、国土交通省の主催により、１月２７日から１月３０日まで開催される。

本会議は、国土技術政策総合研究所の国際会議室にて１月２７日（火）と２８日（水）の両日にわたって行われ、６つのセッションにおいて、日本側は１０論文、ドイツ側は９論文が発表され、討議が行われる。

本会議ののち１月２９日から１月３０日にかけて、東京都下水道局の芝浦処理場・有明処理場・海水浄化プラント、京都市下水道局の鳥羽処理場、滋賀県琵琶湖環境部の市街地排水浄化対策事業施設の現地調査を行う予定である。

（１）委員構成

日本側委員団は、国土技術政策総合研究所の宮原下水道研究部長を団長として、国土交通省下水道部、国土技術政策総合研究所、土木研究所、厚生労働省国立保健医療科学院、大阪産業大学、日本下水道事業団、東京都下水道局、京都市下水道局からの委員で構成される。

ドイツ側委員団は、ドイツ連邦教育科学研究技術省の Heidborn（ハイドボーン）研究部長を団長として、カールスルーエ研究所、アーヘン工科大学、ダームシュタット工科大学、ブラウンシュバイク工科大学、ヴィッテン/ヘルデッケ大学、ベルリン水道事業体、技術コンサルタント会社からの委員で構成されている。(参考１参照)

（２）会議プログラム

本会議では、「下水道行政」、「規制と評価」、「化学物質の管理」、「流域における水システム」、「下水処理技術」、「下水汚泥の有効利用」の６セッションにおいて、対策が必要となっている課題や最新技術についての発表を行い、日独双方にとって有益な情報交換および技術交流の場とすることを目的としている。(参考２参照)

参考1

「第9回日独排水及びスラッジ処理についてのワークショップ」委員構成

(ドイツ側委員)

ハイドボーン博士	団長、ドイツ連邦教育科学研究技術省、研究部長(環境分野)
フアマン工学修士	カールスルーエ研究所、プロジェクト次長
コーネル博士	ダームシュタット工科大学、WAR研究所教授
ディヒトル博士	ブラウンシュバイク工科大学、衛生研究所教授
フラー博士	カールスルーエ研究所、プロジェクトマネージャー
ハインツマン博士	ベルリン水道事業体、研究開発課長
ミューラー博士	カールスルーエ水技術センター、上級研究員
ルドルフ博士	ヴィッテン/ヘルデッケ大学、環境工学マネジメント研究所科学部長・教授
シェアー工学修士	技術コンサルタント会社、下水道技術上級研究員
モンタークエ学修士	アーヘン工科大学、衛生研究所グループ長

(日本側委員)

浜口　達男	国土技術政策総合研究所、所長
宮原　茂	団長、国土技術政策総合研究所下水道研究部、部長
藤木　修	国土交通省都市･地域整備局下水道部、流域管理官
高橋　正宏	国土技術政策総合研究所下水道研究部、下水道研究官
藤生　和也	国土技術政策総合研究所下水道研究部下水道研究室、室長
吉田　綾子	国土技術政策総合研究所下水道研究部下水道研究室、研究員
中島英一郎	国土技術政策総合研究所下水道研究部下水処理研究室、室長
斎野　秀幸	国土技術政策総合研究所下水道研究部下水処理研究室、研究員
鈴木　穣	土木研究所材料地盤研究グループリサイクルチーム、上席研究員
南山　瑞彦	土木研究所材料地盤研究グループリサイクルチーム、研究員
田中　宏明	土木研究所水循環研究グループ水質チーム、上席研究員
岡安　祐司	土木研究所水循環研究グループ水質チーム、研究員
菅原　正孝	大阪産業大学人間環境学部都市環境学科、教授
酒井　憲司	日本下水道事業団技術開発部、部長
村上　孝雄	日本下水道事業団技術開発部、総括主任研究員
山本　博英	日本下水道事業団技術開発部、主任研究員
国包　章一	厚生労働省国立保健医療科学院水道工学部、部長
北村　清明	東京都下水道局計画調整部技術開発課
稲波　文雄	京都市下水道局施設部施設課、担当係長

(オブザーバー)

齋藤　正樹	厚生労働省健康局水道課水質管理室
安中　徳二	元下水道部長（日本下水道事業団理事長)
京才　俊則	元土研副所長（株式会社西原中央研究所所長)
佐藤　和明	元土研下水道部長（河川環境管理財団技術参与)
鈴木　建	東京都下水道局計画調整部技術開発課、主査
森田　健史	東京都下水道局計画調整部技術開発課
宮原　誠二	京都市下水道局施設部施設設計課
斎藤　健次郎	元公共下水道課長（荏原総合研究所専務)

(幹事)

吉田　敏章	国土技術政策総合研究所下水道研究部下水道研究室
田隅　淳	国土技術政策総合研究所下水道研究部下水処理研究室
寺田　真紀子	国土技術政策総合研究所下水道研究部、事務係長
宮本　綾子	土木研究所材料地盤研究グループリサイクルチーム
諏訪　守	土木研究所材料地盤研究グループリサイクルチーム

参考2

第9回日独排水及びスラッジ処理についてのワークショップ　プログラム

第1日目

日付	時間	セッション / トピック	発表者	所属
1/27 (火)	10:30 - 11:00	**開会**	浜口　所長 宮原　部長 ハイドボーン　博士	国総研 国総研 BMBF
	11:00 - 12:00	**セッション 1: 下水道行政** -下水道事業における流域管理 -組織の構造、費用、料金	 藤木　流域管理官 ルドルフ　教授	 本省 Univ.W/H
	12:00 - 13:00	昼食		
	13:00 - 14:00	**セッション 2: 規制と評価** -ディスポーザー使用による下水道システムへの影響 -EUの第6次調査研究枠組みプログラム(2002-2006)	 吉田(綾)　研究官 フアマン　工学修士	 国総研 FZK
	14:00 - 14:10	休憩		
	14:10 - 15:40	**セッション 3-1: 化学物質の管理** -日本の下水におけるエストロゲン様物質の存在状況 -下水汚泥コンポストに含まれる内分泌かく乱物質の施用後の消長 -ベルリン市の水循環における微量物質の存在状況と挙動、及び、その飲料水との関連性	 岡安　研究員 南山　主任研究員 ハインツマン　博士	 土研 土研 BWW
	15:40 - 15:50	休憩		
	15:50 - 16:50	**セッション 3-2: 化学物質の管理** -水道水中の化学物質の管理 -ドイツにおける浄水技術の現状	 国包　部長 ミューラー　博士	 保医科 WTCK
	18:00 -	歓迎会		

第2日目

日付	時間	セッション / トピック	発表者	所属
1/28 (水)	9:00 - 10:00	**セッション 4: 流域における水システム** -下水処理水中の衛生学的指標の消長 -連邦教育科学技術省プログラム「分散型の(代替的)水システム」	斎野　研究官 フラー　博士	国総研 FZK
	10:00 - 10:15	休憩		
	10:15 - 11:45	**セッション 5-1: 下水処理技術** -欧州における膜分離活性汚泥法の現状 -都市下水処理における膜分離活性汚泥法の特性 -公共下水処理場におけるのリン回収	コーネル　教授 村上　総括主任研究員 モンタック　工学修士	TUD 事業団 TUA
	11:45 - 13:00	昼食		
	13:00 - 14:00	**セッション 5-2: 下水処理技術** -IWA(国際水協会)活性汚泥モデルの革新 -統合システムのオンラインシミュレーションと最適化—下水処理場と管路システム	北村 シェアー　工学修士	東京都 CE
	14:00 - 14:15	休憩		
	14:15 - 15:45	**セッション 6: 下水汚泥の有効利用** -下水汚泥の炭化システムと炭化製品の特性 -汚泥分解による費用最小化—実規模での比較 -京都市での溶融結晶炉による汚泥有効利用	山本　主任研究員 ディヒトル　教授 稲波　担当係長	事業団 TUB 京都市
	15:45 - 16:15	**閉会**	高橋　下水道研究官 ハイドボーン　博士	国総研 BMBF
	18:00 -	ドイツ代表団による返礼レセプション		

本省:　国土交通省
国総研:　国土交通省国土技術政策総合研究所
土研:　土木研究所
事業団:　日本下水道事業団
東京都:　東京都下水道局
京都市:　京都市下水道局
保医科:　厚生労働省国立保健医療科学院

BMBF:　Federal Ministry of Education, Science Research and Technology
FZK:　Research Center Karlsruhe
WTCK:　Water Technology Center Karlsruhe
Univ.W/H:　Witten/Herdecke University
TUA:　Aachen University of Technology
TUD:　Darmstadt University of Technology
TUB:　Braunschweig University of Technology
BWW:　Berlin Waterworks
CE:　Consultant Engineers Ltd.

別添２　ワークショップ日程（英文）

Program of 9th Japanese-German Workshop on Waste Water and Sludge Treatment

1st Day

Date	Time	Session / Topics	Presenter	Affiliation
Jan 27 (Tue)	10:30 - 11:00	**Opening**	Mr. T. Hamaguchi Mr. S. Miyahara Dr. J. Heidborn	NILIM NILIM BMBF
	11:00 - 12:00	**Session 1: Wastewater Administration** -Watershed Management Approach in Sewage Works -Organisational Structures, Costs and Fees	 Mr. O. Fujiki Prof. Dr. K. U. Rudolph	 MLIT Witten/ Herdecke University
	12:00 -13:00	Lunch		
	13:00 - 14:00	**Session 2: Regulations and Evaluation** -Impacts of Food Waste Disposers on Sewage Systems -The Sixth Research Framework Programme of the Eropean Union (2002-2006)	 Dr. A. Yoshida Dipl.-Ing. D. Fuhrmann	 NILIM FZK
	14:00 - 14:10	Coffee Break		
	14:10 - 15:40	**Session 3-1: Management of Chemicals** -Occurence of Estrogen-Like Substnaces in Wastewater in Japan -Fate of Endocrine Disruptors Contained in Composted Sludge after Land Application -Occurrence and Behaviour of Trace Substances in the Partly Closed Water Cycles of Berlin and its Relevance to Drinking Water	 Mr. Y. Okayasu Mr. M. Minamiyama Dr. B. Heinzmann	 PWRI PWRI Berlin Waterworks
	15:40 - 15:50	Coffee Break		
	15:50 - 16:50	**Session 3-2: Management of Chemicals** -Management of Chemicals in Drinking Water -State-of-the-Art in Drinking Water Tratment in Germany	 Dr. S. Kunikane Dr.U. Mueller	 NIPH Water Technology Center Karlsruhe
	18:00 -	Welcome Reception		

2nd Day

Date	Time	Session / Topics	Presenter	Affiliation
Jan 28 (Wed)	9:00 - 10:00	**Session 4: Water Systems in Watershed**		
		-Fate of Sanitary Indicators in Treated Wastewater	Mr. H. Saino	NILIM
		-The BMBF Program "Decentralized (Alternative) Water Systems"	Dr. R. Furrer	FZK
	10:00 - 10:15	Coffee Break		
	10:15 - 11:45	**Session 5-1: Wastewater Treatment Technology**		
		-State of the Art on MBR in Europe	Prof. Dr. P. Cornel	Darmstadt University of Technology
		-Characteristics of MBR in Municipal Wastewater Treatment	Dr. T. Murakami	JSWA
		-Recovery of Phosphates in Municipal Waste Water Treatment Plants	Dipl.-Ing. D. Montag	Aachen University of Technology
	11:45 - 13:00	Lunch		
	13:00 - 14:00	**Session 5-2: Wastewater Treatment Technology**		
		-Innovation of Activated Sludge Model Developed by IWA	Mr. K. Kitamura	Tokyo Metropolitan Government
		-Online Simulation and Optimization of an Integrated System – Wastewater Treatment Plant and Sewer System	Dipl.-Ing. M. Scheer	Consultant Engineers Ltd.
	14:00 - 14:15	Coffee Break		
	14:15 - 15:45	**Session 6: Beneficial Use of Wastewater Sludge**		
		-Sewage Sludge Carbonizing System and Properties of Carbonized Products	Mr. H. Yamamoto	JSWA
		-Cost Minimisation by Disintegration – A Full Scale Comparison	Prof. Dr. N. Dichtl	Braunschweig University of Technology
		-Beneftical Use of Sludge by Melting Crystallization Furnace in Kyoto City	Mr. F. Inanami	Kyoto City
	15:45 - 16:15	**Closing**	Dr. M. Takahashi	NILIM
			Dr. J. Heidborn	BMBF
	18:00 -	Return Reception by German delegates		

BMBF: Federal Ministry of Education, Science Research and Technology
FZK: Research Center Karlsruhe

MLIT: Ministry of Land, Infrastructure and Transport
NILIM: National Institute for Land and Infrastructure Management, MLIT
PWRI: Public Works Research Institute
JSWA: Japan Sewage Works Agency
NIPH: National Institute of Public Health, Ministry of Health, Labour and Welfare

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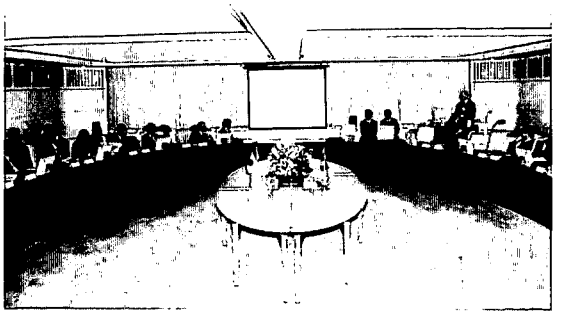
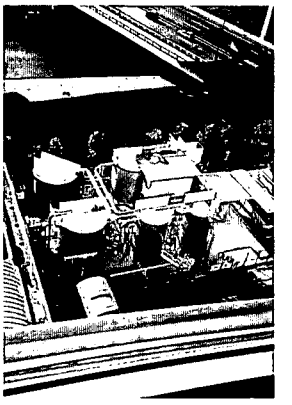
別添４　会議及び現地調査の写真



写真－１　会議の様子（国総研会議室）

写真－２　集合写真（同左）

写真－３　中央監視室（芝浦処理場）



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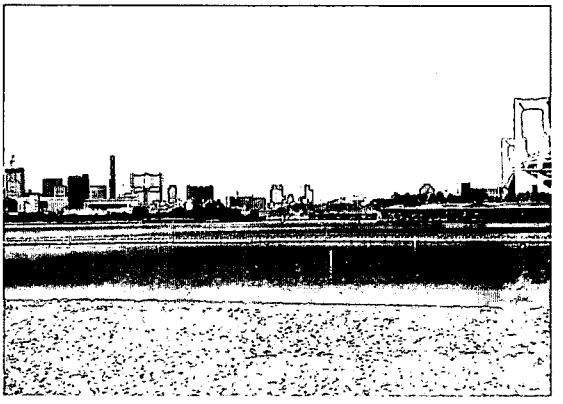

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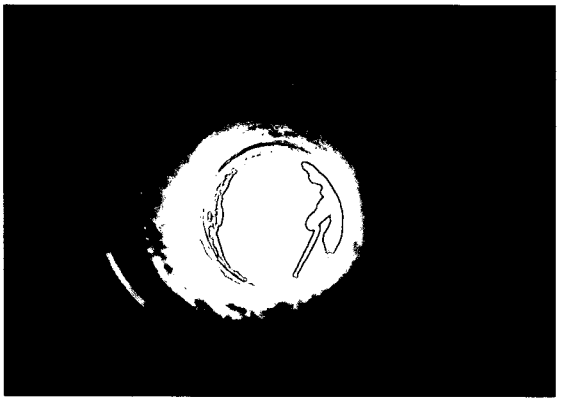

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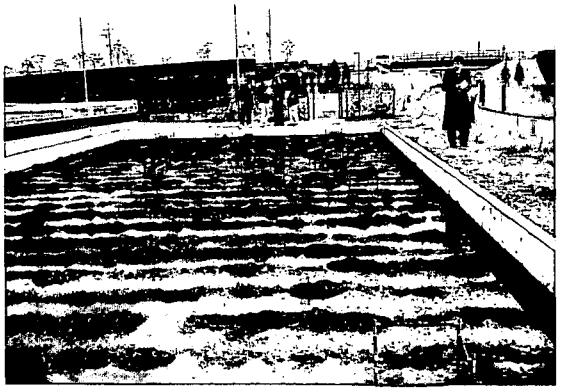
写真－７　放流状況
（山寺川市街地排水対策事業施設）



写真－８　植生浄化施設
（山寺川市街地排水対策事業施設）

5．発表論文

Watershed Management Approach in Sewage Works

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KEYWORDS: Watershed management, Comprehensive Basin-wide Plan for Sewerage Systems, Tokyo Bay Renaissance, Water quality trading

1. INTRODUCTION

In April 2003, the Sewerage and Watershed Management Subcommittee, which was set up by the Urban Planning and Historical Landscape Section of the Social Infrastructure Council of the Ministry of Land, Infrastructure and Transport, published a report entitled "The Policy Concept of Sewerage Construction/Management and Watershed Management". This report was epoch-making in that it gave a definition to "the approach to watershed management". The definition is as follows:

Bringing together sewerage managers in the basin, tying them up extensively with other bodies including local citizens and businesses, and among those stakeholders,

(1) sharing a common concept and purpose,

(2) sharing the risks and the burdens required to reduce them, and

(3) while reducing overall risks and burdens to the minimum, promoting the achievement of common objectives via co-operation

The report calls above-mentioned approach "watershed management approach" in sewage works.

In order to address water-related issues including water pollution, this issue must be identified as a common problem for local governments and citizens/businesses in the basin, and a variety of efforts such as wastewater treatment must be mobilized effectively. The "Comprehensive Basin-wide Plan of Sewerage Systems (CBPSS)" is a typical example of the watershed management approach in sewage works. As compared with other water administrations, a sewerage administration strongly suggests the necessity of "the watershed management approach", because sewerage managers are all local authorities, i.e. municipalities and prefectures. One river basin generally has plural municipalities, and the benefit of sewage works spreads over wider area beyond administrative boundaries.

Hereinafter, the concept and practices of CBPSS are outlined. CBPSS was legislated into Sewerage Law in 1970 and have been formulated in over 100 river basins across the country. Following focus is the new policy on Tokyo Bay Renaissance. This policy is unique in that it was established in the basic policy of "Urban Renaissance" of the Government of Japan and all the

ministries and agencies concerned are involved. Finally the study on water quality trading is described. The study has just started in order to rationally approach the consensus on the best combination and cost-allocation of advanced treatment between sewage treatment plants.

2. COMPREHENSIVE BASIN-WIDE PLAN OF SEWERAGE SYSTEMS (CBPSS)

CBPSS typifies the watershed management approach in water administration in Japan.

2.1 Aim

CBPSS is a master plan of sewerage systems which Article 2-2 of the Sewerage Law obliges each prefecture government to formulate in principle for pollution control in all the public water bodies where water environmental quality standards are set on the basis of Article 16 of Basic Environment Law. In order to achieve and keep fulfilling the standards through sewerage construction and management most effectively, CBPSS is formulated as a master plan of individual sewerage projects from the viewpoint of watershed management.

2.2 Planning Items of CBPSS

CBPSS is drawn up for the public water body that is polluted by wastewaters discharged by the sources in two or more municipal areas. The main items described in CBPSS are as follows:

(1) basic policy relating to sewerage construction
(2) effluent discharge from sewerages and planning of sewage treatment areas
(3) basic layout, structure and capacity of main sewerage facilities
(4) priority of undertaking of sewerage projects

After liaison with the relevant authorities and then referring to the opinions of the municipalities, prefecture government draws up a draft of the plan. In the case of the water bodies pertaining to plural prefectures, relevant prefecture government is supposed to have conference with the Ministry of Land, Infrastructure and Transport (MLIT) as well as the other relating prefecture governments for the adjustment on the assignment of pollution load reduction to prefectures concerned. On the basis of reached consensus, draft CBPSS is submitted to MLIT, which then gives approval to the prefecture's request after discussing the planning proposal with the Ministry of Environment.

2.3 Assignment of Allowable Loads to Prefectures

As mentioned above, when the basin extents over two or more prefectures, agreement must be reached between the relevant prefectures regarding the pollution load reduction before the formulation of CBPSS in each prefecture. The agreement is basically made on the "allowable pollution load" representing a load discharge permit that should be fulfilled for the water body to achieve its environmental standards. Regional bureau of MLIT plays an important role in making adjustments between prefectures, taking fairness and efficiency into account, on the basis of the simulation of pollution loads and water quality.

The assignment of allowable loads to prefectures was finished in Tokyo Bay, Osaka Bay, Ise Bay and Seto Inland Sea, as well as for major rivers such as Tone, Kiso and Yodo Rivers. Figure 1 shows an image of the assignment of allowable pollution loads to prefectures relating to Tokyo Bay.

In March 1997, the committee on CBPSS for Tokyo Bay was held by the Kanto Regional Construction Bureau of the Ministry of Construction (the present Kanto Regional Development Bureau of MLIT), and the consensus shown in Table 1 was reached regarding the future

allowable pollutions loads between Tokyo Prefecture, Kanagawa Prefecture, Saitama Prefecture, and Chiba Prefecture.

Table 1. Assignment of Allowable Load Targets between Prefectures Relating to Tokyo Bay (t/day)

	COD	Total Nitrogen	Total Phosphorus
Tokyo Metropolitan Area	56	73	3.5
Kanagawa Prefecture	27	30	1.3
Saitama Prefecture	41	38	1.7
Chiba Prefecture	68	54	3.3
Other areas	26	25	0.7
Total	218	220	10.5

Note: Other areas mean northern three prefectures above Metropolitan areas. Pollution loads come also from these areas via Tone River into Tokyo Bay.

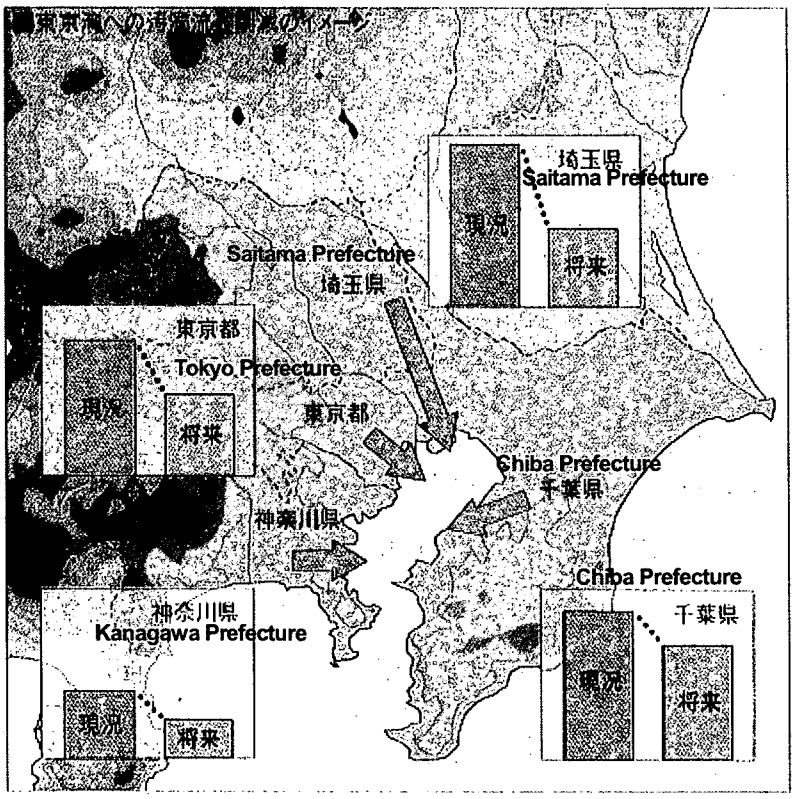

Figure 1. Image of Future Allowable Pollution Loads in Tokyo Bay Basin
Left histogram: present load, Right histogram: future allowable load

In Tokyo Bay basin, assuming that the construction of sanitary sewer network will be almost finished by the target year of 2012, load was estimated for each prefecture as of 2012 and allowable load was assigned to each prefecture in this proportion. However, allowable pollution load is generally assigned to each prefecture in proportion to the load contribution in base year to water quality at the point of observation.

The result of subtracting the allowable load from the future load, which is projected on the assumption that no additional measures will be taken before the target year, is defined as "load reduction". The load reduction is assigned not only to sewage treatment plants, factories and other point sources, but also to non-point sources such as urban areas and agricultural areas. Natural loads such as forests, plains and rain are in principle not taken into account for the load reduction assignment. In this case, load reduction is often assigned assuming that all sources, which are assigned load reduction, should achieve the same reduction rate. However, there are actually no legal guaranties whatsoever for any point sources other than sewerage. In other words, CBPSS scheme has no legal effect on the factories, even if the load reduction is assigned to them in the formulating process of CBPSS.

In the planning process of CBPSS for Tokyo Bay, the load reduction is assigned to the related sources as shown in Figure 2

Table 2. Assignment of Load Reduction to Sewerage (t/day)

	Future Load	Allowable Load	Load Reduction	Load Reduction by Sewerage
COD	326	218	108	66
Total N	405	220	185	174
Total P	26	10.5	15.5	14.1

Figure 2 shows the assignment of nitrogen load reduction among sources in Tokyo Bay Basin.

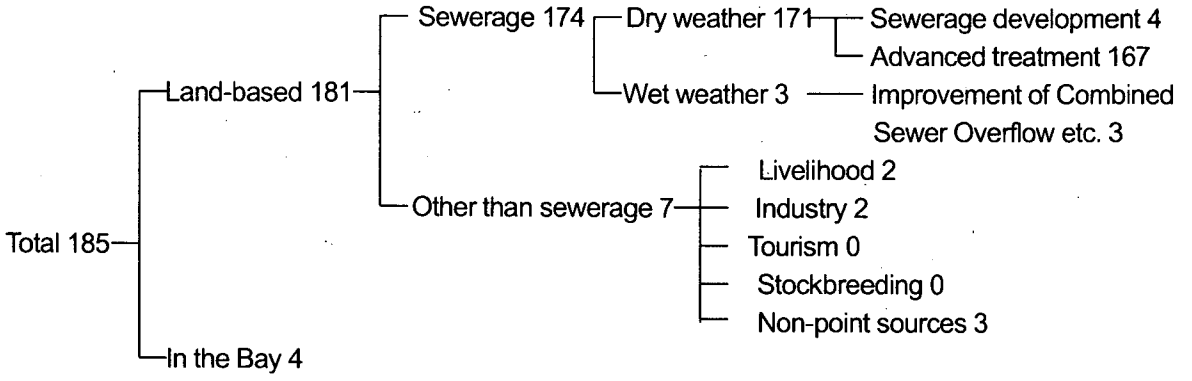

Figure 2. Assignment of Total Nitrogen Load Reduction in Tokyo Bay Basin (t/day)

After the assignment of load reduction relating to sewerage among prefectures, each prefecture government assigns its own portion between sewerages. This assignment is often made assuming that the water quality of future effluent should have almost no difference between sewage treatment plants. But some prefectures set more stringent load reduction for large-scale treatment plants than for small scale..

2.4 Implementation of CBPSS

About 200 CBPSSs are supposed to cover almost whole of Japan, and 123 plans have already been drawn up as of January 2003.

3. ACTION PLAN FOR TOKYO BAY RENAISSANCE

3.1 Urban Renaissance Project "Ocean Renaissance"

The Urban Renaissance Headquarters chaired by the Prime Minister was established on the basis of the Cabinet decision in May 2001 to promote urban revitalization projects which are creating new society of 21st century from the viewpoints of the environment, disaster prevention and internationalization, and to promote general consolidation of policies aimed at urban revitalization such as making effective use of land resources. The Urban Renaissance Headquarters, in its fifth meeting (December 2002), decided the basic policy of "Ocean Renaissance" for the Metropolitan area where water pollution has become a chronic problem. The policy includes the formulation of "Action Plan for Tokyo Bay Renaissance (Action Plan)", through collaboration among relevant authorities such as related local authorities and government agencies, focusing in particular on the water quality improvement in offshore coastline areas.

To develop and effectively promote the Action Plan for better water quality, in February 2002, was established "Tokyo Bay Renaissance Conference (Conference)" in which four prefectures including the Metropolis of Tokyo, three major cities and related government ministries/agencies participate. The Conference set up following subcommittees: "Organizing Subcommittee", "Land-based Measure Subcommittee", "Ocean-based Measure Subcommittee" and "Monitoring Subcommittee".

As a result of the discussion at the Conference as well as Subcommittees, in March 2003, the Conference published the Action Plan, which contains policies and measures to be implemented by relevant authorities to achieve common objectives of restoring Tokyo Bay to a clean, beautiful and ecologically sustainable ocean in 10 years.

The Action Plan, as shown below, has some unique features, and is full of suggestions for the future policy-making of watershed management.

(1) Ocean renaissance is evaluated from the viewpoint of regenerating the urban environmental infrastructure in the Metropolitan area.

(2) This is a joint project between local authorities and relevant government ministries.

(3) It poses not only environmental standards for the ocean environment, but also local targets which are close to the needs of the urban population.

3.2 Action Plan for Tokyo Bay Renaissance

3.2.1 Objectives

The Action Plan puts forward the objectives outlined below from the viewpoint that city residents can understand them easily. It is also recognized that we need to promote initiatives for

improvements through the cooperation and joint activities of a wide range of parties concerned, including administrative agencies.

Objectives

We will seek to recover a familiar and beautiful sea and to create opportunities to comfortably enjoy recreation activities in and near the water. We want a Tokyo Bay that enhances the quality of life for residents of the metropolis and a marine environment in which many organisms can live.

In order to assess how far this objective is being achieved, the bottom layer DO (dissolved oxygen) was selected for the common index of the achievement. It is a marker indicating daily stresses on benthic organisms living all the year around.

3.2.2 Key Areas

In accordance with the objectives outlined above, key areas were employed corresponding to regional needs, on the basis of the evaluation of the current environment and water use situation.

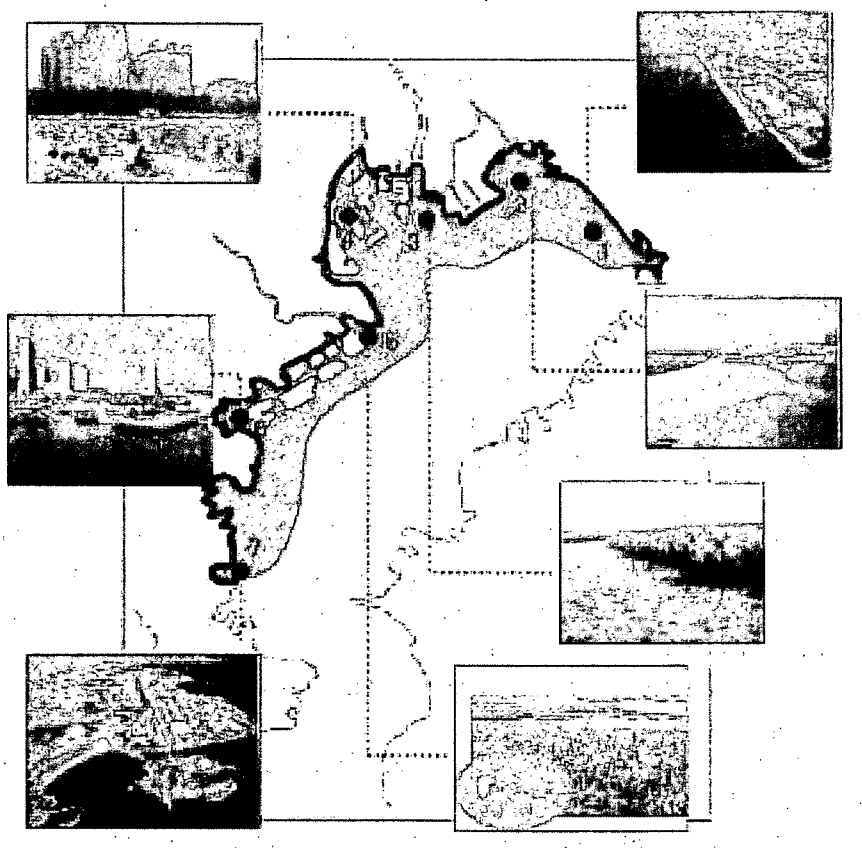

Figure 3. Key Areas and Appeal Points
Key areas , Appeal point: ●

Scope of key areas: Offshore of coastline from Kanazawa Ward in Yokohama City and Chuo Ward in Chiba City
Key areas concept:: Areas to be improved with special emphasis for Tokyo Bay Renaissance

Appeal points concept: Places where citizens will be able to readily feel the effect of the improved environment as a result of the measures taken—places where we can plainly evaluate the effects of the measures. (The appeal points are different from the sites where actual measures are taken.)

Seven representative points (appeal points) have been selected and the image of improvement, corresponding indexes and targets are described for each point as shown in Figure 3 and Table 3.

Table 3. Outline of Appeal Points

No.	Point name	Location	Image after improvement	Indexes	Aims, objectives: Environmental evaluation classification for 7 prefectures and cities; "objectives that city residents can understand"
1	Vicinity of Inage and Makuhari Beach	Sites around artificial beaches at Inage, Kemigawa and Makuhari	Beaches with greenery for comfort and recreation	- Environmental evaluation classification of 7 prefectures and cities (Note 1) - Organisms	- Above environmental evaluation classification Level II for 7 prefectures and cities (Note 2) - Water environment where organisms such as blowfish, goby, short-necked clam and lugworm can live.
2	Vicinity of Sanbanse	Precious tideland and shallow maintained in deepest areas at head of bay	Protection of natural environment of Sanbanse and restoration of the sea as amenity for residents	Study results of work of Sanbanse Renaissance Plan Study Group	Study results of work of Sanbanse Renaissance Plan Study Group (Ref.) Objectives at stage of interim summary To secure: - Living species and environmental diversity - Continuity between land and sea - Sustainability and recuperative power of environment - Productivity of fishing grounds - Citizens' enjoyment of nature
3	Vicinity of Kasai Seashore Park	The waters around park and Sanmaizu	Protection of natural environment and tideland/beach for animals	- Environmental evaluation classification for 7 prefectures and cities - Organisms	Above bottom environmental classification Level III - Environment where short-necked clam and trough shell can live - Environment where little tern can build nests
4	Vicinity of Odaiba	Odaiba Seaside Park and Sibaura Canal	Beautifully landscaped waterfront enjoyable for citizens	- Environmental evaluation classification for 7 prefectures and cities - Organisms - Water quality	Above bottom environmental classification Level III - Environment where short-necked clam and Japanese dosinia can live - In fiscal 2015, eliminate days (zero days/year) when white solids (fats) from combined sewer system drift ashore on rainy days at Odaiba Seaside Park. - Water purification experiment at Odaiba Seaside Park will aim at objective water quality stated below. (Experiment to be conducted between 2002 and 2005.) COD 5mg/l Fecal coliforms 100pieces/ 100mL
5	Vicinity of Tamagawa River mouth	Waters surrounding tidelands near Tamagawa River Mouth and Hanedasu	Raise diverse animals; create beach rich with nature	- Environmental evaluation classification for 7 prefectures and cities - Organisms	Above environmental evaluation classification Level II for 7 prefectures and cities - Sea environment where short-necked clam, freshwater clam, lugworm, mud skipper, goby, Japanese seaperch, Chigogani and Ashiharagani can live. Environment where longbill, plover, little

					tern, oriental reed-warbler, spot-billed duck, gallinule and other wild birds come more frequently and build nests without fear.
6	Vicinity of Minato Mirai 21	Waters around Yokohama Port Inner Harbor	Water amenity zone open to citizens. Waterfront where people can feel port atmosphere.	- Environmental evaluation classification for 7 prefectures and cities - Water quality - Organisms	- Above environmental evaluation classification Level II for 7 prefectures and cities - Achieve and maintain water environment targets for Yokohama City - Sea environment where blowfish and sea perch can live and brown seaweed and other plants form marine forest.
7	Vicinity of Sea Park and Hakkeijima	Bathing beach at Kanazawa and marine recreation waters	Waterfront where people can enjoy various marine sports such as bathing, shellfish gathering and fishing.	- Environmental evaluation classification for 7 prefectures and cities - Water quality - Organisms	- Above environmental evaluation classification Level III for 7 prefectures and cities - Achieve and maintain water environment targets for Yokohama City - Marine environment where Japanese whiting and Osagani can live, and eelgrass and other seaweed form marine forest.

Note 1. Environmental evaluation classification for 7 prefectures and cities means the bottom environmental evaluation classification set by the Specialized Subcommittee for Improving Water Quality, the Committee for Measures against Environmental Problems at the Summit of 7 Prefectures and Cities.

Note 2. This aim was set on the basis of the current status at a distant observation point due to absence of an observation point near the appeal point. Readers must consider this point.

3.2.3 Period of the Plan

The period of the plan is the ten-year starting in fiscal 2003.

3.2.4 Promotion of policies to achieve the objectives

(1) Measures to Reduce Land Pollution Loads

(a) To reduce pollution loads from the land, specific measures should be efficiently implemented, while steadily pursuing the Plan for Reduction of Area-wide Total Pollutant Load.

(b) Advanced treatment for preventing eutrophication should be promoted in addition to the development of conventional wastewater treatment

- Advanced treatment should be started in about 20 sewage treatment plants.

(c) Wet weather load should be reduced.

- The combined sewer systems should be reconstructed so that the total load of BOD may be reduced to the level of separate sewer system.

(d) In addition to the removal of organic pollution load by river purification facilities or dredging, the reduction of nutrients should be promoted for the restoration of swamps and estuary tidelands.

(e) To reduce the load from non-point sources, sound growth of trees and thickness of the underbush by proper thinning and development of multiple-layered forests should be promoted. Also, treatment of storm water and control of storm water runoff by installing storage and infiltration facilities should be conducted to reduce the pollutant loads from non-point sources..

(f) Regarding the collection of floating garbage, the efforts of local citizens should be promoted.

(g) Cost allocation should be studied for sharing the total cost appropriately among stakeholders in the basin including the application of economic instruments.

(2) Promotion of Environmental Improvement Measures in the Sea

(a) Reduction of ocean area pollution load

- Regarding the accumulated organic substances in canals, etc, efforts should be made to effectively remove the bottom mud (improving bottom sediment by development of shallows using good sediments (covering sand) originating from dredged sludge or good-quality soil).
- There is a plan to use cleanup ships to completely collect and remove garbage floating on the ocean surface. The development of the technology to recover red tide and its application should be conducted.
- Efforts to collect garbage on the seabed and clean up beaches or tidelands in cooperation with NPOs and fishing association should be promoted.

(b) Enhancement of Purification Function in the Sea Waters

- Existing, precious tidelands and shoal should be conserved as much as possible while maintaining harmony with the other public welfare.
- Tidelands, shoals, beaches and stony shores will be reclaimed/created.
- Harbor structures should be developed to accelerate adhesion of living organisms. Gently sloping seawalls, reclaiming deep ditches, aeration of seawater should be promoted to create an ecological environment for bottom marine lives.
- From the point of long-term view, an information network on tidal flats and shallow water areas should be established.

(3) Monitoring of Tokyo Bay

(a) Improvement of Monitoring

- The monitoring of bottom layer DO and benthic organisms should be strengthened.
- Ocean currents and water quality should be monitored extensively by monitoring posts and ships
- Events such as the red tide should be monitored in real time by artificial satellites.

(b) Sharing and Transmission of Monitoring Data

- A website to collect pertinent information should be set up together with related links.

(c) Community Monitoring Activities

- Beach cleaning and classification survey of drifting garbage should be performed in cooperation with local residents.
- Cooperation with NPOs that perform environmental conservation activities such as "Sea Guards" in Tokyo Bay should be strengthened.
- More opportunities should be provided where environmental conservation activities performed by citizens and NPOs can be presented to the public.

3.2.5 Other

(1) Experimental Initiatives

(a) Water purification by the Metropolitan Government in Odaiba

(b) Monitoring by regular ferries

(c) Observation by marine shortwave radar

(d) International exchanges

(2) Follow-up on the Action Plan

The progress of the Action Plan should be followed up, while assessing and promoting its steady implementation. The Action Plan should be reviewed as necessary.

4. STUDY ON WATER QUALITY TRADING BETWEEN SEWAGE TREATMENT PLANTS

4.1 Background

In the Action Plan for Tokyo Bay Renaissance, it is determined that the cost allocation should be studied for sharing the total cost appropriately among stakeholders in the basin including the application of economic instruments. Also, the report "Opinions on Businesses and Enterprises - towards an Autonomous, Self-governing Local Community" which was published by the Council for Decentralization Reform in October 2002, proposed that "cost-sharing in the whole basin should be considered from the viewpoints of the responsibilities of both dischargers and beneficiaries in order to efficiently achieve the objectives of water quality environmental standards in basin units".

On the basis of these plan and proposal, the MLIT set up "Study Committee on Water Quality Trading between Sewage Treatment Plants" in 2002, which performed investigations based on simple model calculations for pollution load discharge permit trading targeted at advanced sewage treatment in Tokyo Bay basin.

4.2 Pollution Load Discharge Permit Trading Model Targeted at Sewage Treatment Plants in Tokyo Bay Basin

In order to quantitatively appreciate the effect of discharged load limits trading on total cost reduction, a simple trading model was designed for advanced sewage treatments in Tokyo Bay basin.

(1) Assumptions

(a) Targeted areas: Tokyo Bay basin (Tokyo Metropolitan Area (Tokyo Prefecture), Kanagawa Prefecture, Saitama Prefecture, Chiba Prefecture)

(b) Targeted pollutant to be traded: equivalent total COD obtained by converting nitrogen and phosphorus into COD considering eutrophication in addition to COD. Equivalent COD was defined as COD+3.24xT-N+51.09xT-P in this study.

(c) Targeted sewage treatment plants: 77 municipal sewage treatment plants in Tokyo Bay basin

(d) Pollution load: to simplify the model, completion of secondary treatment is assumed for all the sewerage systems.

(e) The baseline for the trading is assumed to be the same as the assignment of allowable load targets between prefectures relating to CBPSS for Tokyo Bay. (See Table 1)

(2) Concept of the Model

(a) Load reduction according to each categorized advanced treatment option

The pollution load discharge for each categorized advanced treatment option is calculated by "daily effluent flow x categorized effluent water quality". Table 4 shows the categorized effluent water quality for each treatment level. Pollution load reduction is obtained by the difference between thus calculated load discharges.

(b) Estimation of marginal unit cost for every advanced treatment option

- The marginal cost of advanced treatment of level 1 was estimated based on querying survey toward municipalities. The marginal unit cost is the marginal cost divided by load reduction.
- The unit costs of level 2 and level 3 were obtained by multiplying the marginal unit cost of level 1 by the unit cost ratios, which were estimated through studies on standard model cases.

-Marginal unit costs of level 2 and 3 are the differences between above unit costs of level 2 and 1, and level 3 and 2, respectively.

(c) Balanced price in trading

- Arrange the advanced treatment options according to marginal unit cost, and then accumulate the load reduction of options in this order. (See Figure 5) When the accumulated load reduction reaches the goal of total load reduction, then the marginal unit cost of final option is the balanced price.

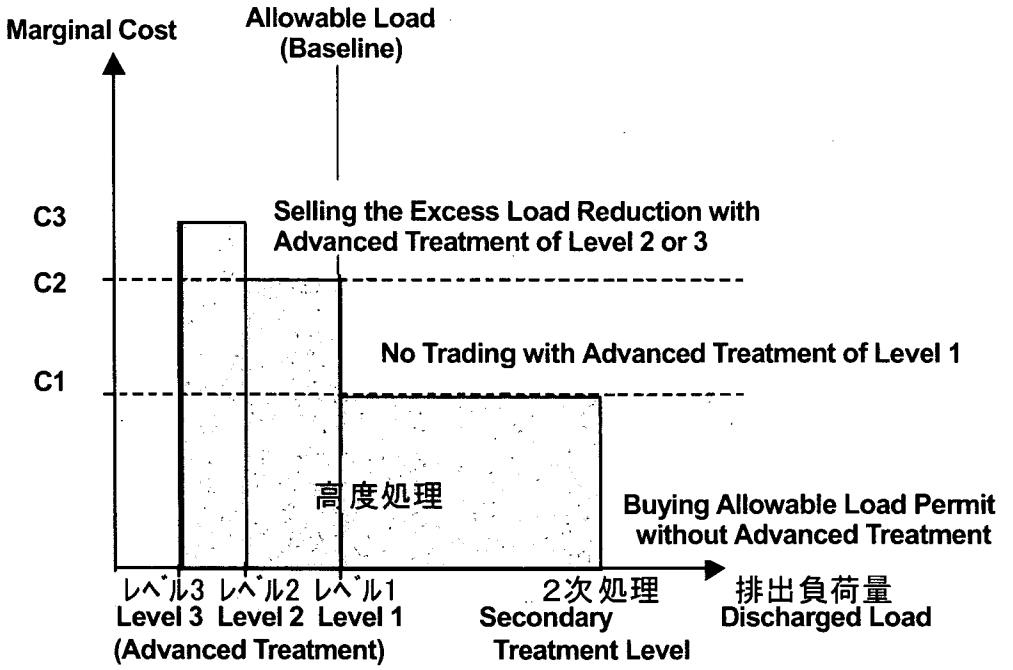

Figure 4. Estimation of Load Reduction and Its Cost for 3 Options of Advanced Treatment

Table 4. Effluent Water Quality for Categorized Treatment Option (mg/L)

	Secondary Treatment	Advanced Treatment		
		Level 1	Level 2	Level3
COD	15	8	8	5
T-N	25	8	5	3
T-P	2.0	0.4	0.2	0.1
Example Method	Conventional Activated Sludge	A2O	Flocculants addition +Step-feed multistage denitrification-nitrification	Level 2 +Post-denitirification

(3) Effect of Load Trading (Cost Reduction Effect)

(a) Overall effect

As the result of the simulation of water quality trading relating to advanced sewage treatment in Tokyo Bay basin, it was shown that a maximum overall cost reduction of about 10% could be expected. (See Figure 5)

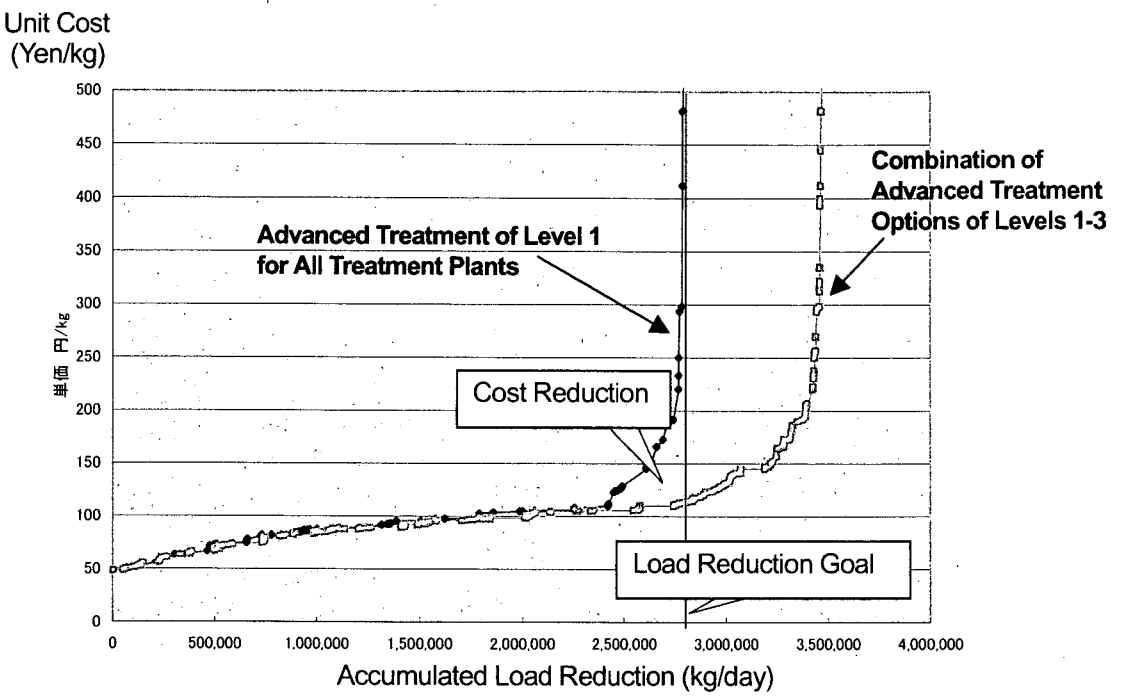

Figure 5. Accumulated Load Reduction in Order of the Options of Lower Unit Cost

(b) Cost reduction effect for each prefecture

Tokyo Prefecture is a seller, while Saitama Prefecture, Chiba Prefecture and Kanagawa Prefecture are buyers of load discharge permit, as a whole. Cost reduction ratio is about 10% in Saitama Prefecture, Chiba Prefecture and Tokyo Prefecture, and about 20% in Kanagawa Prefecture

(c) Difference in cost reduction effect between treatment plants

Of 77 treatment plants, 23 treatment plants are buyers, and 46 treatment plants are sellers. 8 treatment plants are neither buyers nor sellers, because they select the advanced treatment plant of level 1. The cost reduction is a maximum of 90% on the buyer side and a maximum of 28% on the seller side.

(d) Leveling effect on burdens between treatment plants

Although the unit costs of advanced treatment of level 1 vary widely among treatment plants, the net expenses (=cost of advanced treatment + payment, or – receipt in the trading) of all the treatment plants converge to some range as the result of trading. The burdens, therefore, are leveled between treatment plants.

5. THE FUTURE OF WATERSHED MANAGEMEN APPROACH IN JAPAN

Watershed management approach is a pregnant key word for policy-making in addressing water-related issues in general. Particularly this approach is needed in sewerage administration, because local authorities conducting sewage works are apt to focus on their own benefits alone, leaving public welfare beyond their administrative boundaries.

Inundation Control Law in Specific Urban River Basin was enacted last June on the basis of the concept of watershed management approach. According to this law, all the stakeholders including citizens as well as prefecture governors, mayors, river managers and sewerage managers in the river basin are regulated and obliged to do their duties. For example nobody can develop building estate over regulation scale without storm water runoff control. Relevant public sectors must go into partnership with each other to establish the Basin-wide Plan of Inundation Control (BPIC), which stipulates public authorities in the river basin take concerted actions toward the prevention against flood and inundation damages. Sewerage managers are, therefore, supposed to take joint responsibility for inundation control in the whole river basin together with the river manager and other public authorities concerned.

CBPSS and BPIC typify the legally realized scheme of watershed management approach. But many water-related problems still remain for solution through watershed management approach in Japan.

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"Wastewater Administration"
Session 1

ORGANISATIONAL STRUCTURES, COSTS AND FEES

by K.-U. Rudolph*

ABSTRACT

The development of the German wastewater sector is described, focused on organisational structures, cost and fees. For these, figures are given and compared with other countries.

KEYWORDS

Wastewater, statistics, connection rates, laws, regulation, costs, organisation, privatisation.

CONTENTS

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0. INTRODUCTION

The scientific co-operation and exchange of knowledge between Japan and Germany is of specific interest, especially in the wastewater institutional sector:

- Both countries are fully industrialised and developed democratic societies with very high requirements and standards for wastewater management.

- In Japan, the population density, the size of the metropolitan regions is even higher than in Germany. Strong tropical storm waters create additional difficulties, compared to the Central European rainfalls.

- On the other hand, the coastline in Germany is far away from large metropolitan areas, and sewage discharge to the sea was no technical option for most of the settlements.

- The whole country of Germany is classified as "sensitive area", including not only the long and (often) shallow rivers, but also the coastal regions.

This is the reason, why the wastewater sector in Germany began to develop earlier than in other countries, including UK, France, USA.

Regarding organisational structures, Germany's wastewater sector is (by law) operated under public responsibility. Privatisations happen, but only with respect to the specific needs of regulation and control in the wastewater sector. Unlike UK or France, the organisational set-up of the German water sector reflects the issues and discussions prevailing the Japanese development, especially regarding the issue of privatisation. [1]

1. HISTORICAL DEVELOPMENT

Germany was industrialised early on and is a densely-populated country. Unlike in England or Japan, it was not possible to pipe wastewater out of congested urban areas into the ocean by short routes.

At the end of the 1960's / beginning of the 1970's, the water pollution in the Federal Republic of Germany reached a level that caused grave concern. During the years of rapid economic growth, water protection measures could not keep up with the expansion of industrial activities.

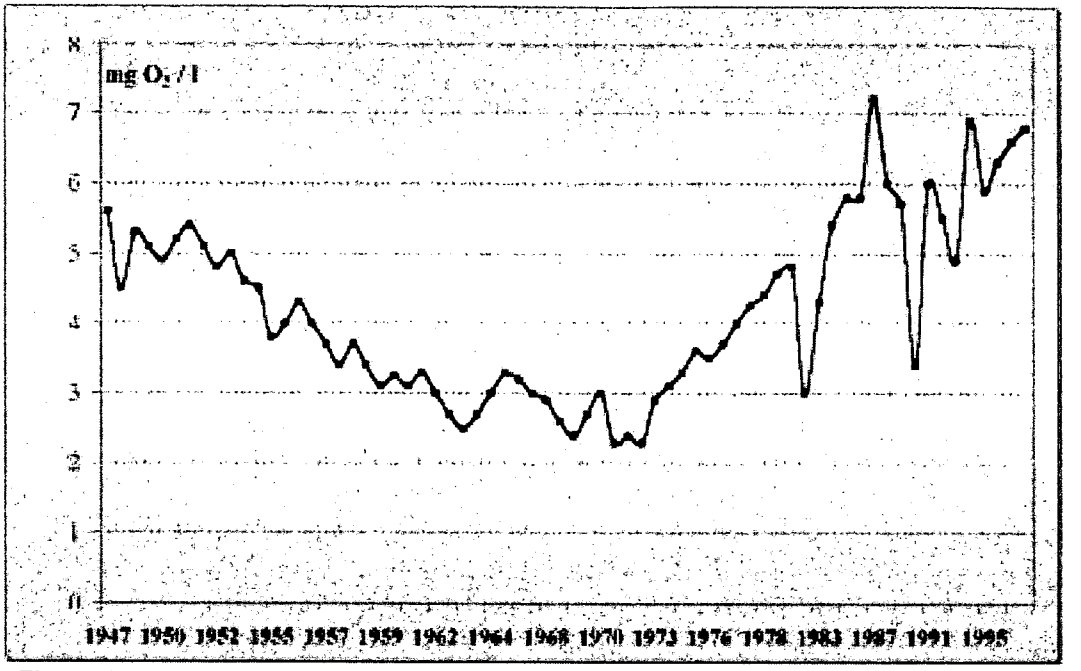

Figure 1: Development of the oxygen concentration of the Rhine [2]

With the construction of over 8,000 biological WWTP's in the municipal sector, as well as intensive wastewater treatment and supplementary internal measures in industrial enterprises, the emission of contaminants and oxygen-consuming, organic wastewater components into bodies of water has been significantly reduced. Decisive improvements in the quality of surface waters have thereby been reached.

At the time of the reunification of Germany in 1989, the water bodies in the eastern part of Berlin and in the newly-formed German states - Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt, and Thuringia - were, in part, dramatically contaminated. They needed to be quickly and effectively cleaned up. This required the joint efforts of the nation, the municipalities, the states, and the economy in a national solidarity action with substantial financial means. More than 2,000 WWTP's were erected, hundreds of kilometres of sewer pipes were laid, and entire branches of industry were cleaned up.

Today, Germany is one of the most advanced countries, within Europe and world-wide, in the area of water technology and water management. This is not only true with respect to end-of-pipe water protection (e.g. well-constructed WWTP's with a high percentage of hook-ups), but also with respect to a prudent use of drinking water.

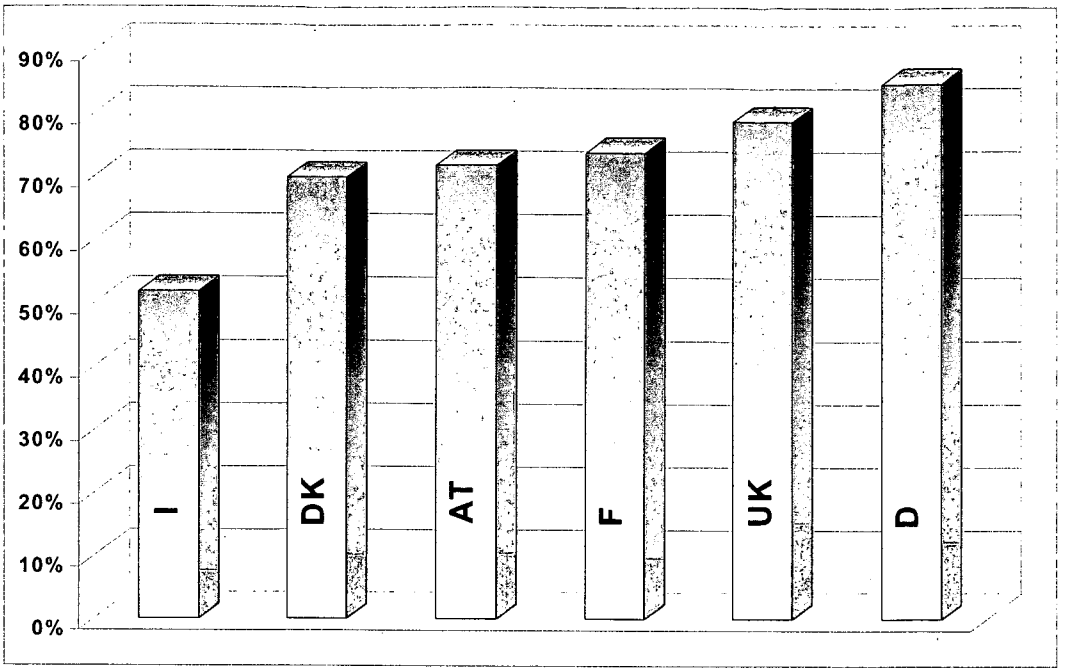

Figure 2: EU-comparison - percentage of wastewater treated in fully biological WWTP`s [3]

The responsibility for water bodies does not stop at national borders. The federal government has accordingly made international co-operation for the protection of seas and inland waters a special emphasis of its environmental policies. In the European Union, the German government is working towards common requirements for water protection on a high level.

The results of the implementation of this water protection policy can be seen in the development of the water quality in Germany. On the following page are maps depicting Germany's water quality in the years 1975, 1985, 1989, and 1995. The coloured sections indicate the quality class of the water bodies in each respective year. Due to the change in the past few years, a positive development in the quality of water in Germany has emerged.

2. INSTITUTIONAL FRAMEWORK

Germany has a federal structure: the responsibilities of government are divided among the national, state, and municipal levels. The *federal government*, with its headquarters in Berlin since reunification, is responsible for promulgating a national legislative and defining national tasks of water management. There are several federal ministries for various specialised fields: the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit* - http://www.bmu.de) is responsible for the protection of water bodies; the Federal Ministry of Economics and Technology (*Bundesministerium für Wirtschaft* - http://www.bmwi.de) oversees water supply systems and the water industry; the Federal Ministry of Education and Research (*Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie* - http://www.bmbf.de) is in charge of developing new technologies; and the Federal Ministry for Health (*Bundesministerium für Gesundheit* - http://www.bmgesundheit.de) ensures the quality of drinking water. International cooperation is overseen by the Federal Ministry for Economic Cooperation and Development (*Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung* - http://www.bmz.de). The ministries have at their disposal advisory authorities, such as the Federal Environmental Agency (*Umweltbundesamt* - http://www.umweltbundesamt.de) and the Federal Institute of Hydrology (*Bundesanstalt für Gewässerkunde* - http://www.bafg.de), as well as private, commissioned agencies, such as the Project Agency for Water Technology (*Projektträger Wassertechnologie* - http://www.fzk.de) or the Organisation for Technical Co-operation (*Gesellschaft für technische Zusammenarbeit* - http://www.gtz.de).

The *state governments* of the 16 federal states are responsible for the regulation of water supply and wastewater disposal in their territories, within the framework of the federal laws.
The organisation and implementation of the water supply and wastewater disposal belong to the traditional duties of the *municipalities*, in accordance with state water laws. In order to cover incurred expenses, the municipalities charge consumers with tariffs and fees. The municipalities must also maintain smaller water bodies in their jurisdiction.

How do the involved members at the various levels and in the various institutions co-operate in German water management?

First of all, whoever wishes to utilise natural the water resources or water bodies must apply for a permit. Applicants are mostly municipalities, water utilities, or industry that desire to construct a groundwater abstraction facility or waterworks, for example, making use of groundwater. Even when a development area or industrial park is to be built and a regular wastewater disposal system (WWTP and sewer system discharging into a river) is planned, an application for authorisation is still necessary. With the application for authorisation, not only the technical designs need to be submitted, but also (depending on the scope and significance of the project) emission reports, environmental compatibility studies, etc.

The application for authorisation is submitted to the responsible authorising agency. These are (in most states) the so-called lower water authorities (located in county government offices) for "smaller" projects and the upper water authorities (located in district government offices) for "larger" projects. These water authorities use their advisory authorities at the respective levels - that is, the water management or

environmental bureaus [4]. A fundamental, democratic element is the hearing of third parties - for example, nature protection organisations, citizens' action committees, or concerned individuals - which takes place for important decisions through strictly regulated procedures.

If authorisation is granted after examination of legal and technical conditions, the proposed project may be carried out, with the observance of the applicable environmental standards and, if the case may be, special requirements for construction and operation.

The definition of standards takes place at various levels. The overlying framework is anchored in the European Union legislation, including especially the following:

- Directive 2000/60/EC Water Framework Directive (http://europa.eu.int/eur-lex)
- Directive 91/271/EEC, concerning the handling of municipal wastewater
- Directive 96/61/EC, concerning the integrated pollution (IPPC Directive)
- Groundwater Directive (80/86/EEC)
- Drinking Water Directive (98/83/EC)
- Nitrate Directive (Directive 91/676/EEC)
- Pesticide Directive (91/414/EEC)
- Water Protection Directive, concerning the emission of hazardous substances into water bodies (76/464/EEC)
- Bathing Water Bodies Directive (76/160/EEC).

German federal law has been and continues to be conformed to this European law and further developed in consideration of the specific, high demands of an environmentally compatible, organised industrial status. At the federal level, the most important regulations within this framework are:

- The Water Management Act
- The Drinking Water Ordinance
- The Groundwater Ordinance
- The Wastewater Ordinance
- The Effluent charge Act
- The Act on the Impact Assessment of Washing and Cleaning Agents
- The Fertiliser Agents Ordinance.

These federal regulations are further substantiated at the level of the 16 German federal states. Corresponding to the individual circumstances and political objectives of each respective state, a state water law, state effluent charge act, etc. has been empowered.

The requirements and standards are formulated most concretely at the lowest level, where framework requirements of the respective superordinate level must be observed. For example, the final decision with regard to treatment standards for a WWTP is made by the municipality. Nevertheless, the municipality must still heed the conditions set by the district government; the district government, on the other hand, must observe the minimum requirements set by the state and federal governments, which must conform to the EU directive (for municipal wastewater). There are more than a few cases in Germany whereby a municipality has voluntarily installed excessively high-performance wastewater treatment technology (with especially good phosphate elimination or additional wastewater disinfection). In very "sensitive" river catchment areas, the district government (or as the case may be, the state government) determines legal limits

which are significantly stricter that the minimum requirements in the state (or federal) laws (as is the case in the catchment area of Lake Constance, in Bavarian bathing lakes, or at the Baltic See coast).

In the political process, starting from the first discussion through to the final decision, a close network formed between the various decision-making bodies and the municipal council, the county parliament, the Bundestag, etc. Into this network are integrated also all the scientific associations and interest groups, which exert influence - at so-called hearings, for example - on important new legislation.

The advantage of such a federal, several-layered structure is that one is able to include all interested parties and experts. For the local parties responsible for water management issues (that is, especially municipal and private enterprises and the water-consuming industry), it is necessary to heed the multitude of laws and regulations with their organisational and technical specifications.

In view of the decentralised decision-making structure, however, it is difficult in Germany to implement all of the central specifications of the European legislation in proper form and in due time. Therefore, complaints have been raised by the EU not only against nations with a less-developed protection of water bodies, but also against the Federal Republic of Germany - despite its undisputedly high standard of execution in comparison with the rest of Europe (Figure 2). The following figure shows the percentage of private households in Germany connected to wastewater disposal. This is representative of Germany's end-of-pipe protection of water bodies.

The supply of water, and even more so the disposal of wastewater, has traditionally been a responsibility of the municipalities. With the increase of technology, the corresponding, gradually rising costs, and, in part, financial bottlenecks, numerous other organisational forms besides the traditional municipal department have been developed and realised (corresponding to the respective requirements of the specific location and political environment) in the last twenty years.

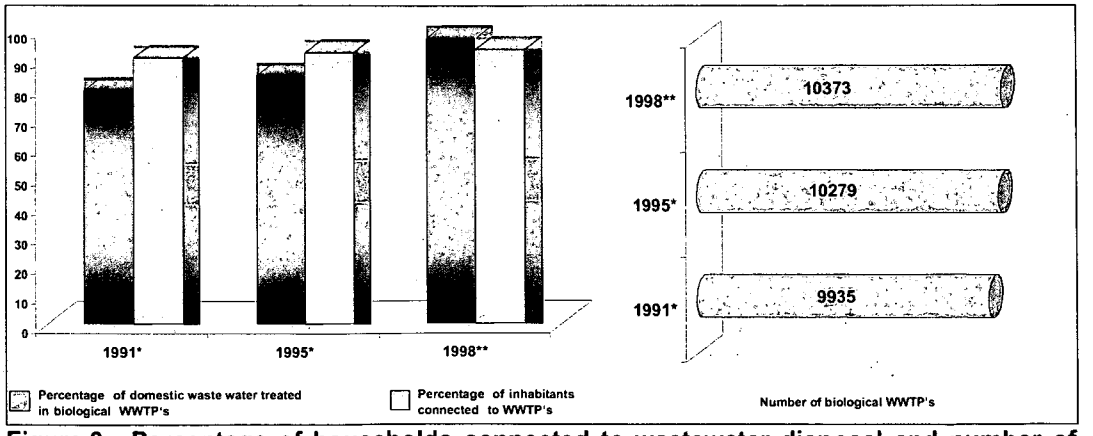

Figure 3: Percentage of households connected to wastewater disposal and number of biological WWTPs [5, 6]

Due to its federal structure and decentralised decision making process, Germany is most certainly the nation with the greatest diversity of organisational forms, whereas the majority of the ca. 450 cases with private involvement consist of a combination of various models for private involvement [7]. The municipalities have a prominent position in Germany because of the legal situation. The national water market is not

dominated by international corporations, as is the case in some other European countries, but rather by a multitude of chiefly medium-sized enterprises and municipal companies [8].

The co-operation between municipalities in water and wastewater associations plays a special role in Germany. This co-operation emerges mostly voluntarily, but it is sometimes also initiated by the state. The associations work to make the organisation of water supply and wastewater treatment, the maintenance of water bodies, and water protection more technically and economically efficient. They differ from one another according to tasks, regional size and form of organisation.

Organisational forms of water supply and wastewater disposal systems

By virtue of the federal and state laws, municipalities are free in choosing the organisational form of "their" wastewater disposal. The municipalities may decide for themselves (according to their political and economical preferences), if and to what to degree they want to privatise or not. There are no central specifications for the so-called "delegation of duties to a third party". Complete privatisation, however, is only permitted in a few states, and then only under considerable stipulations. The most common organisational forms are as follows:

Municipal department (Regiebetrieb):

Operated by the municipality within the scope of the regular municipal administration.

Municipal utility (Eigenbetrieb):

Operated by the municipality in a separate capacity with independent bookkeeping.

Municipal company (Eigengesellschaft):

Private entity company in the hands of the municipality.

Joint venture (Kooperationsmodell):

Municipal utility with the involvement of a private firm.

Operator model – BOO, BOOT, BOT, etc. (Betreibermodell):

Delegation of the plant operations to a private firm, whereas the responsibility for the fulfilment of tasks remains with the municipality.

Management and service contract (Betriebsführungsmodell):

The plant property belongs to the municipality, but the operations and any further management tasks are delegated to a private firm.

Depending on jurisdiction, it is possible that boundaries for associations, water utilities, and municipalities overlap, so that outsiders have difficulty recognising the organisational structure. Therefore, there are water supply associations or private long-range water utilities whose boundaries of operation do not coincide with the boundaries of the local water utilities, which are supplied by the former. Similarly, there are large-scale wastewater associations which are responsible solely for long-distance transportation and for wastewater treatment and whose boundaries do not match up with the municipalities or disposal companies. These municipalities and disposal companies, on the other hand, handle wastewater collection through local sewer systems.

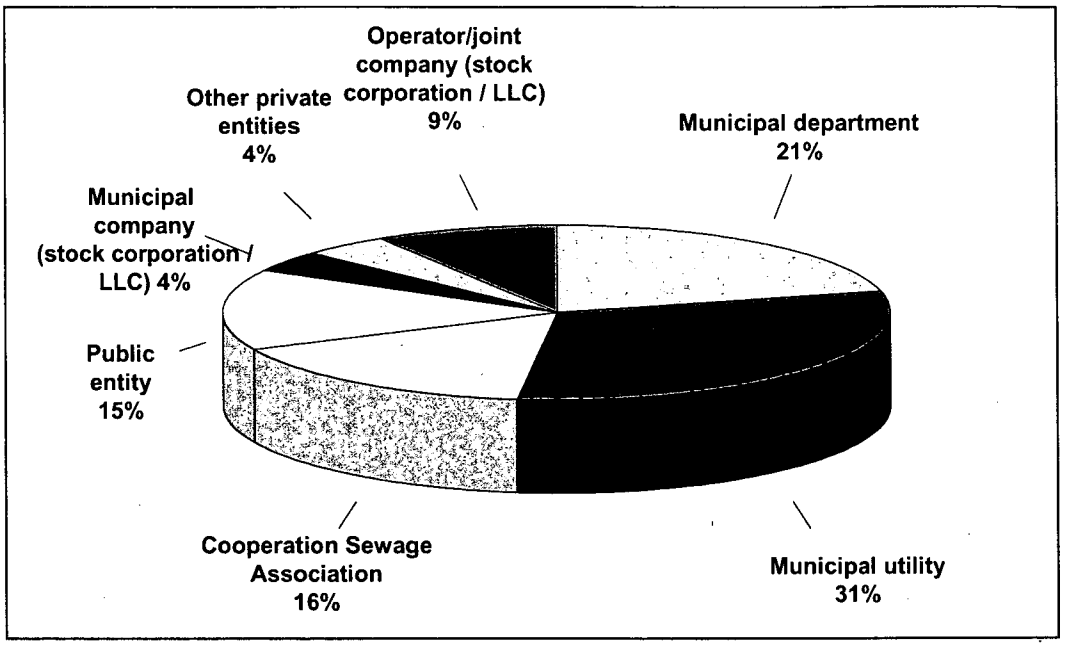

Figure 4: Implementation of wastewater handling in Germany (in % of total population) [own assessments, based on data from the water industry (BDE) and ATV as of 2001]

There is also variation in the composition of the decision-making bodies of regional associations, municipal parliaments, municipal committees, member assemblies of associations, and supervising councils and advisory boards of private water utilities.

It becomes apparent that the strength of Germany's water management lies by no means in a central and tightly-organised arbitration or in the controllability of the system "from above". Its strength is found rather in the obligatory and widespread hearing of experts and interested parties of all relevant groups and in the *democratic and constitutional consideration of various interests and viewpoints*. This all leads in the end to a consensus, or as the case may be, to a compromise. The more drawn-out and difficult the way to a consensus or compromise is, the more pertinent and successful the implementation of the solution will be.

2.1 IMPORTANT, SPECIFIC REGULATORY INSTRUMENTS

The technical and economical regulation of water management takes place in Germany on the basis of the above-mentioned laws according to various operative principles that supplement one another. The following regulatory instruments will be addressed in greater detail:

- Price control
  With various regulations for the supply of water and disposal of wastewater.

- Financial incentives
  By which the participants' interest in a sustainable use of water bodies is to be strengthened. For example, the abstraction of groundwater or the discharge of wastewater is controlled by charges (Water Abstraction Fee - *Gundwasserentnahmeentgelt*; Effluent Charge - *Abwasserabgabe*).

- Minimum requirement standards
  With quality requirements for drinking water or, as shown below, for effluent from WWTP's, corresponding to the Ordinance on Wastewater - as well as standards for the technology and operation of plants.

- Prohibitions and obligations
  Mostly for the limiting of substances hazardous to water bodies, as is then shown in the example of the Act on Washing and Cleaning Agents.

Beyond these, there are several environmentally relevant principles in the area of water management (Figure 5). They concern the fundamentals of a sustainable water management policy which, in practice, cannot be perfectly implemented at all times and in all places. Nevertheless, these principles offer the decisive orientation for politics and the economy in view of a sustainable use of resources.

2.1.1 MUNICIPAL CHARGES ACT AND ANTITRUST LAW

Price mechanisms for water supply are based on principles and regulations which differ from those of wastewater disposal. *Wastewater disposal* is subject to the cost recovery principle; that is, the municipalities responsible for wastewater disposal allocate the costs to the consumers, but they may not include a profit margin.

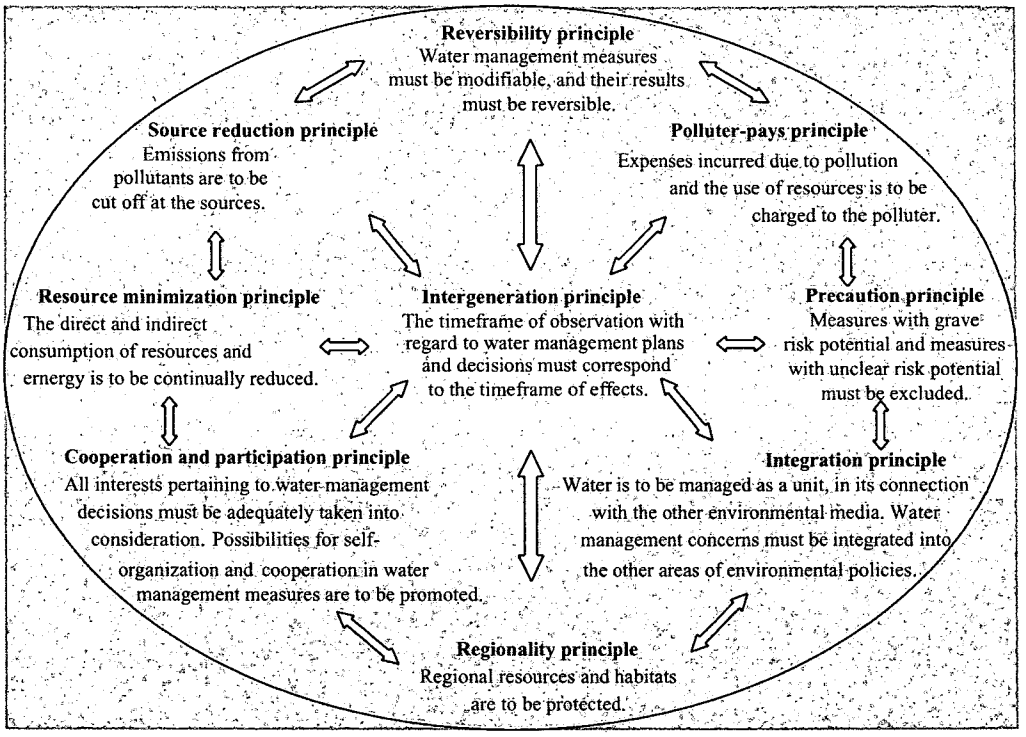

Figure 5: Interaction of principles relevant to water management [9]

In practice, there is an abundance of precepts and relevant court decisions dealing with approaches in the individual cost positions. Figure 6 presents an overview of types of costs and their part in the calculation of wastewater fees.

Water supply systems organised as private entities are regulated in a different manner. The municipality is not responsible for their supervision, but rather the antitrust agency (which, incidentally, also regulates the supply of gas and electricity). Upon inquiry, water utilities must be able to verify, and if need be, demonstrate, that their water prices are not higher than those of comparable companies and suppliers.

If the antitrust agency conducts an investigation due to suspicion of "misuse of pricing", the technical standard and cost structures are closely examined and then compared to those of similar companies (which corresponds, in part, to Cost Benchmarking - *Kosten-Kennzahlenvergleich*).

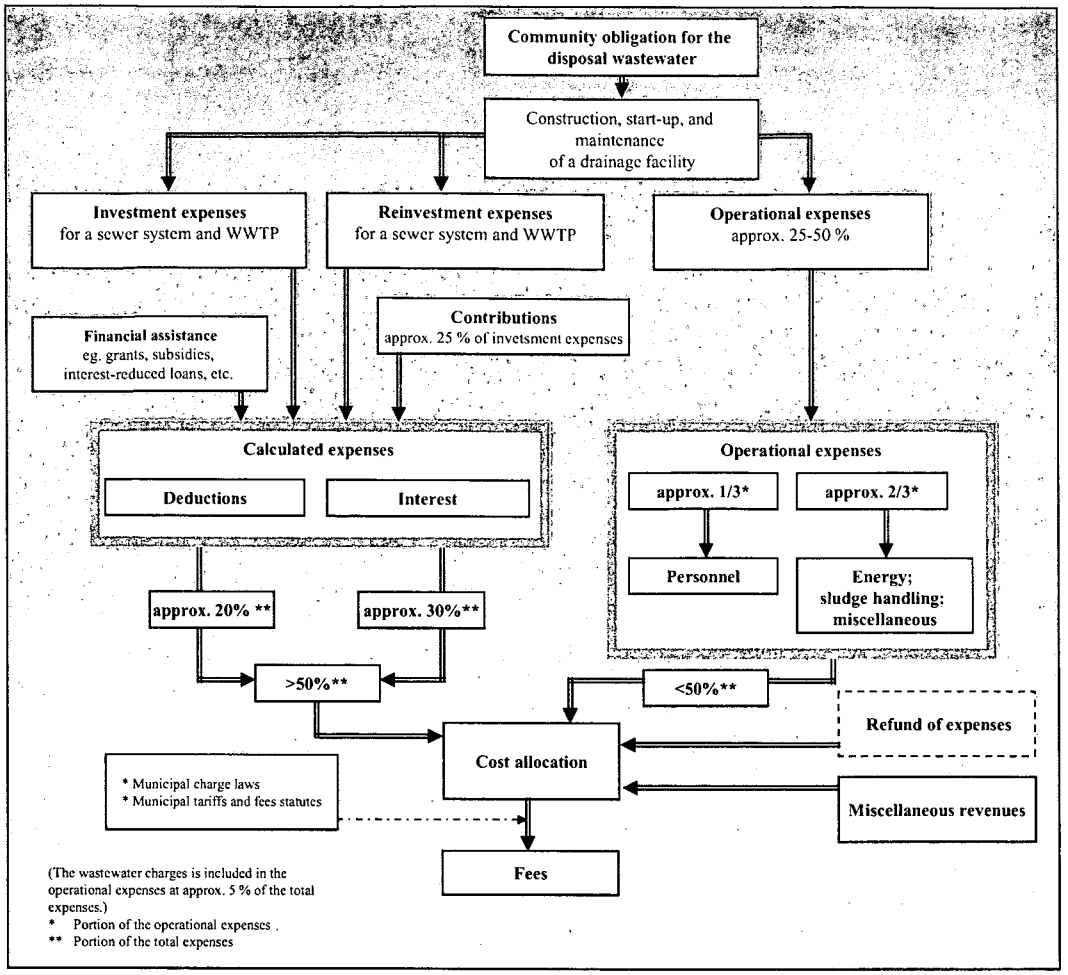

Figure 6: Breakdown of the most important types of expenses in wastewater disposal [5]

This approach is essentially not any different than in countries with central price regulation*. Germany's approach differs from these others, however, in that it uses no uniform formulas applied from a central agency, but instead considers each situation individually, which corresponds to Germany's federal, decentralised structure [5, 10].

2.1.2 EFFLUENT CHARGES ACT (*ABWASSERABGABENGESETZ, ABWAG*)

The Effluent Charges Act of 1976 (last amended in 1994) makes the provision that a charge must be paid for the point source discharge of treated wastewater into a water body. Generally, the payment of effluent charges in no way exempts one from the responsibility of treating wastewater. *This charge is the only nation-wide environmental charge in the area of water that functions as a deterrent.* The polluter-pays principle is brought to bear with this charge, for point source dischargers must be held liable for at least a portion of the costs of the utilisation of the environmental resource of water. The charge is calculated according to the amount and harmfulness of the respective substances discharged.

The charge per pollutant has been raised, in several steps, from DM 12 (ca. € 6) in 1981 to DM 70 (ca. € 35) since January 1, 1997. Economic incentives are to be created with this charge for reducing as many point sources as possible. For that reason, the AbwAG (Effluent Charges Act) also provides discounts for cases in which the payer meets certain minimum requirements. In addition, certain investments for the improvement of wastewater handling can be offset against the charge.

The effluent charge is paid to the states. It is to be used strictly for the conservation of water bodies. On average, the effluent charge comprises about 5% of total costs. In Germany, this corresponds to approx. € 5 per inhabitant per year. The economic deterrent function is greater in individual cases, however, since fines need to be calculated into the total if a plant exceeds the so-called monitoring standards. Such fines apply most of all to point source dischargers with deficient WWTP's, but also to operators of modern plants who, because of their poor operation, do not attain to a satisfactory level of treatment.

Table 1: Contaminants and pollution units (*Schadeinheit*, SE)* according to the Effluent Charges Act (AbWAG)

Rated contaminants and contaminant groups	**Measurements constituting one pollution unit**
Oxidisable substances in chemical oxygen demand (COD)	50 Kilograms Oxygen
Phosphorus	3 Kilograms
Nitrogen	25 Kilograms
Halogen compounds as absorbable organic halogen compounds (AOX)	2 Kilograms Halogen as organic chlorine
Metals and their compounds: Mercury Cadmium Chromium Nickel Lead Copper	 20 grams 100 grams 500 grams 500 grams 500 grams 1000 grams metal
Toxicity to fish	3000 cubic meters of wastewater divided by the dilution factor G_F, by which wastewater is no longer toxic to fish

* "One SE corresponds roughly to the harm caused by the raw waste water produced by one inhabitant in one year (inhabitant equivalence)." - http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/waste-water-charges-act.htm

2.1.3 WASTEWATER ORDINANCE (*ABWASSERVERORDNUNG*, ABWV)

The Wastewater Ordinance sets technical standards, such as legally binding pollutant limits, which are for various kinds of wastewater. The ordinance was one of the first measures for the implementation of the sixth amendment to the Water Management Act, which took effect in November 1996. It regulates, among other things, the requirements for the discharge of wastewater within the scope of municipal handling of wastewater and implements European requirements for the protection of water bodies. Altogether, there are 54 appendices with specific regulations for domestic wastewater and for various industries. Table 2 lists some of the appendices for selected industries.

Table 2: Appendices to the Wastewater Ordinance (*Abwasserverordnung*, AbwV)

Area / branch of industry	Example
Municipal disposal	Appendix 1 Municipalities / domestic wastewater
Foodstuffs industry	Appendix 3 Milk processing Appendix 7 Fish processing Appendix 10 Meat processing
Animal feed industry	Appendix 14 Drying of plant products for the production of Animal feed
Chemical industry	Appendix 9 Manufacturing of coating materials and varnish Resins Appendix 22 Chemical industry Appendix 45 Petroleum processing
Metalworking industry	Appendix 24 Part A Iron and steel production Appendix 24 Part B Iron, steel, and malleable iron foundries Appendix 40 Metalworking, metal processing
Waste management industry	Appendix 51 Aboveground landfills
Electrical industry	Appendix 54 Manufacturing of semiconductor components

These discharge requirements are *minimum requirements* within the scope of a federal law. It is left to the states and their water authorities to define and enforce higher standards on an individual basis, where this is necessary due to an especially sensitive water body ecology and other reasons for the protection of the common good. Therefore, there are many municipal WWTP's that have a higher discharge standard than the minimum requirements listed in Table 3.

These standards are to be observed for continuous operation, even in unfavourable pollutant conditions. With regard to the minimum requirements for the parameter $P \leq 1$ mg/l, for example, an even better operational standard (e.g. $P \leq 0.7$ mg/l) is set, in order to maintain a sufficient margin of safety above the minimum requirement. In Germany, if these prescribed standards are not observed, an administrative offence is to be assumed. Under certain circumstances, the violation of the prescribed minimum standards is a punishable act that is prosecuted by the authorities.

Table 3: Minimum requirements concerning the discharge of municipal wastewater according to the AbwV

Size classes of WWTP's	Chemical oxygen demand (COD)	Biological oxygen demand in 5 days (BOD_5)	Ammonium nitrogen	Total nitrogen as total of ammonium-, nitrite-, and nitrate nitrogen	Phosphorus total (P total)
Population units	mg/l*	mg/l*	mg/l*	mg/l*	mg/l*
less than 1,000	150	40	---	---	
between 1,000 and 5,000	110	25	---	---	---
between 5,000 and 10,000	90	20	10	---	---
between 10,000 and 100,000	90	20	10	18	2
larger than 100,000	75	15	10	18	1

1 population unit = 60 g BOD_5/d in untreated wastewater *Qualified sample or 2 hr mixed sample

2.1.4 WASHING AND CLEANING AGENTS LAW

The Washing and Cleaning Agents Law of 1975 (amended in 1994) sets requirements for the environmental compatibility of washing and cleaning agents. The use of water-polluting substances can be forbidden or limited. The law obligates makers of washing and cleaning agents to inform the Federal Environmental Agency (UBA) of the basic contents of their products. Furthermore, the law requires that the consumer be informed by the packaging of the respective product about the most important components and the quantity to be used.

On the basis of the Washing and Cleaning Agents Law, the Ordinance on Surfactants and the Ordinance on Maximum Permissible Amounts of Phosphate were enacted. The Ordinance on Surfactants stipulates that surfactants contained in washing agents must be at least 90% primary biodegradable.

Phosphate-free washing agents have become widely available on the market. Due to this change in cleaning agents, the emission of phosphate into water bodies through washing agents in domestic wastewater had decreased from 42,000 tons of phosphate in *1975* to approx. 2,000 metric tons in *1993* (in the former West Germany).

In addition, in 1993, after foundations were laid with strict criteria concerning the complete biological degradability and the toxicity to water organisms, the "Blue Eco Angel" (a voluntary product symbol) was first awarded to a cleaning agent in the modular construction system, in order to support product users in making their households environmentally friendly. In 1995, criteria that had been worked out under German leadership were passed for a European Environmental Label for cleaning agents.

2.1.5 THE TECHNOLOGICAL REGULATORY FRAMEWORK OF GERMAN WATER MANAGEMENT

The implementation of water management tasks does not just take place on the basis of regulations from governmental agencies. Scientists and representatives of water management work closely together with governmental agencies in the conceptualising of uniform technological specifications. With this approach, the co-operation and participation principles are allowed for in German water management.

The implementation of uniform technological regulations makes a significant contribution to the effective and economical protection of the environment and of real assets. Through the continual process of revising and updating, based on the current state of science and technology, the regulatory framework supports policy issues, administration, and industry. The specifications are important for the designing, constructing, and operating of water supply systems and WWTP's. Even statements concerning the maintenance and monitoring of plants are taken into consideration by experts in the drafting of the regulatory framework. A selection of topics in the technological regulatory framework and its contents are summarised in the following table.

Table 4: Examples of topics in the technological regulatory framework

Area	Contents
Water supply	Protected water areas Mechanical equipment in waterworks Optimisation and cost reduction in waterworks
Drainage systems	Planning / calculating Construction / repair Operation
Municipal wastewater treatment	Assessment Treatment processes Small WWTP's
Industrial wastewater	Technology-related water protection
General water management	Hydrology Groundwater Water quality Ground protection Nature protection and ecology

The following regulatory frameworks, among others, used in German water management are also available in foreign languages:

Table 5: German regulatory frameworks in foreign languages

Regulatory framework	Language
ATV standards (Abwassertechnische Vereinigung e.V. www.atv-dvwk.de)	German; partly in English, French, Spanish, Polish
DIN standards (Deutsches Institut für Normung e.V. www.din.de)	German; partly (depending on demand) in English, French, Chinese
DVGW regulatory framework (Deutsche Vereinigung des Gas- und Wasser www.dvgw.de)	German; some excerpts in English, French, Russian, Polish

German regulatory frameworks and technological standards (DIN: http://www.din.de) are being increasingly adapted into the European standards, the so-called CEN Standards. As a result, legislatures as well as licensing and supervisory authorities revert to such regulatory frameworks in defining standards and in evaluating individual cases.

It is remarkable that such regulatory frameworks arise out of the independent responsibility of experts, organised by professional associations of water management. To such an extent, even regulations and standards are the result of a consensus or compromise-finding process into which various viewpoints have entered. The current trend "away from detailed standard specifications for measures in the sense of input definitions - toward a result-oriented regulation of operational performance in the sense of an output-oriented definition" will help expedite matters so that the dynamic of technological innovations is not slowed down through far-too-sluggish standardisation processes and obsolete regulatory frameworks.

2.2 WASTEWATER DISPOSAL

Every densely-populated area of Germany, without exception, possesses a central wastewater disposal system. According to information from the Federal Statistical Office, the total volume of wastewater in 1998 was approx. 9.6 billion m³, including about 4.9 billion m³ of domestic and commercial wastewater. The predominant amount of wastewater (99.5%) was treated in public WWTP's. Only 0.5% of the wastewater was handled in industrial plants. The portion of external water that entered into the sewer systems in 1998 was estimated at about 2 billion m³. Point source discharges without any treatment were reduced from about 115 million m³ in 1995 to about 65.3 million m³ in 1998.

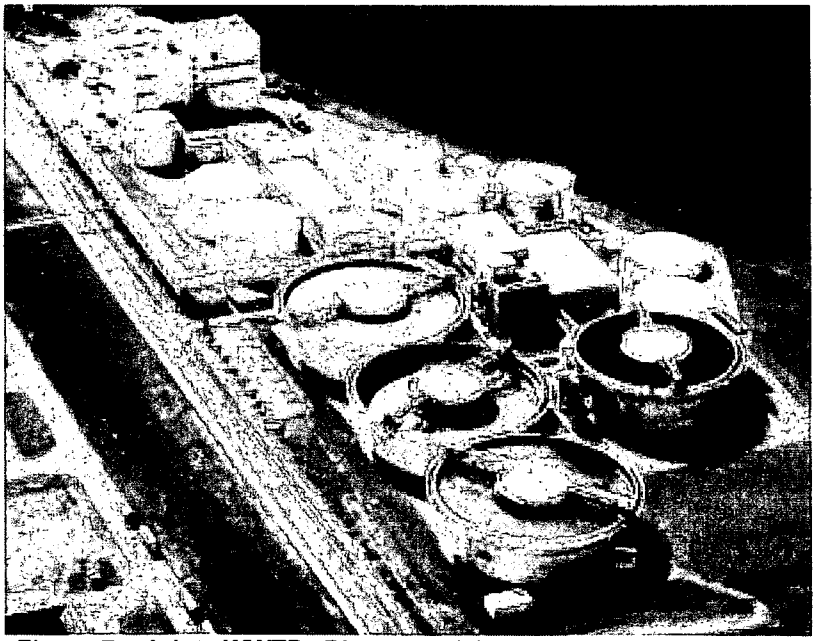

Figure 7: Joint WWTP Bitterfeld (above-ground bioreactor - population equivalent = 453,000) (pilot project of the BMU for the joint handling of domestic wastewater and industrial chemistry wastewater) [11]

From 1970 to 1994, over € 78 billion were invested by the municipalities in former West Germany for the construction, expansion, and renovation of sewer systems and WWTP's. Twenty-three billion Euros went for the expansion of WWTP's, and approx. € 55 billion were appropriated for *investments* in the area of sewer systems. From 1991 to 1996, approx. € 22 billion were invested in the overall area of WWTP's in Germany. The annual expense of municipalities and wastewater associations for public wastewater disposal amounts to over € 6 billion.

The term "wastewater"

The term "wastewater" defines water that ends up in the sewer system and has come from one of these sources: water that has been altered, in particular contaminated, through domestic or commercial use, surface run-off, or rainfall (cf. WHG, AbwAG, DIN 1045). There are thus two kinds of wastewater: contaminated water and meteoric precipitation.

Contaminated water originates, for example, from clean water that has been altered in its chemical or physical properties through use as wash or rinse water. In the Wastewater Charges Act, the distinction is often made whether the alteration of the water is ecologically detrimental, inconsequential, or even advantageous.

Regarding the term "contaminated water", it is irrelevant where the water originates - that is, whether it was taken from groundwater before alteration through use, from surface waters, or from a water supply line.

If the water, however, is extracted only for storage purposes and is discharged again (e.g. at excavation sites), it does not fall under the term "contaminated water", unless it was used for another purpose (e.g. as wash water or for flotation purposes) before it was discharged.

According to 1998 statistics, only 6.8 % of Germany's population was not hooked-up to a public sewer system in that year. With a 93.2% connection, one can speak of a practically complete sewer system in Germany. There are still gaps in the newly-formed German states, where, according to individual states, between 12% (Thuringia) and 31.4% (Brandenburg) of the population is not hooked-up to public sewers. There are connection gaps in other areas of Germany as well, particularly in several rural areas. But even there, wastewater is practically completely disposed of through private septic tanks with periodic faecal sludge removal and treatment.

Altogether, there are approx. 445,700 km of usable public sewers in Germany, about 51% of which are mixed-water sewers, in which contaminated water and rainwater are transported together. There are about 134,000 km of sewers in the public sewer system that only transport contaminated water. In these sewers, faeces are carried off for treatment along with grey water from domestic and commercial use. Rainwater is drained in about 85,000 km of separate rainwater sewers. Alternatively, rainwater seeps away on-site. Besides the public sewer system, there are privately owned sewer systems, as is the case with large industrial enterprises. Accurate figures for the length of these sewers are currently not available.

According to a survey taken by the Association for Wastewater Technology (*Abwassertechnische Vereinigung e.V.* – ATV – http://www.atv.de), 33% of all *sewers* were less than 25 years old or less in 1997. More than one third of all public sewers were between 25 and 50 years old. Eleven percent were in the 50 to 75 year-old age group, and 16% were between 75 and 100 years old. Only 4 % of all public sewers in Germany were more than 100 years old. Somewhere between 40,000 and 80,000 km of public sewers were in need of repair. The repair and modernisation of present systems is a future task in Germany, after all necessary sewers and treatment plants have essentially already been built.

About 60% of the approx. 2.5 million Mg (1998) of *wastewater sludge*-dry matter that accumulates during wastewater treatment is reused. Wastewater sludge is used as fertiliser in the preparation of nutrient-rich soil for agriculture and gardening. However, the high level of recycling in agriculture is to be greatly reduced. According to resolutions by the responsible authorities in the summer of 2001, it is intended that, in the future, sludges be predominantly burned. Responsible for these decisions to "exit" out of recycling wastewater sludge by agricultural means were incalculable microbial and chemical risks with regard to the depositing of wastewater sludge onto agricultural areas. Starting in 2005, no more organic wastewater sludge is to be deposited in landfills. Therefore, thermal resource recovery (e.g. in thermal power plants) will gain in importance.

Although re-investments for upgrading, modernisation, rehabilitation of wastewater plants and networks dominate the needs of the decade, there is a remarkable market potential for improved technologies, especially, if cost-optimised or integrated to lean operational schemes [14]

Mandatory connection and use

In the statutes for wastewater disposal in the municipalities, mandatory connection to and use of wastewater disposal facilities has been made binding for the land within the municipality. Therefore, every property owner in the area of jurisdiction is obligated by these statutes to connect the property to the local wastewater disposal system as soon as wastewater accumulates on the property (mandatory connection). The landowner is then further obligated to discharge the total amount of wastewater generated on the property into the wastewater disposal system (mandatory use). There are also exceptions, however, which the statutes regulate for selected cases, such as agricultural production.

Mandatory connection and use in Germany traditionally belongs to duties delegated to the municipalities and is part of the public health protection policy.

The intended purpose of public wastewater disposal is the continual guarantee of the cleanliness of groundwater, in the interest of the common good. Regulations for exceptions apply to individual solutions; however, they must not be beneficial just for industrial firms or private households, but must be technologically and economically purposeful also for the entire disposal area.

It is obvious that mandatory connection and use involves many conflicts. When centralized water supply system was introduced in rural areas after WWII, in the 1950's and the beginning of the 1960's, there were time and again individual citizens who were satisfied with their own private wells and - despite the many hygienic risks involved in a private water supply - categorically refused to connect to the municipal facility. With regard to wastewater disposal, there are cases still today in Germany in which the connection to central wastewater collection and treatment is fought against with sever means, in one case even with a long-lasting hunger strike. Reasons for such opposition are most often the costs of wastewater disposal, but sometimes also ecological arguments and a grassroots-democratic striving for autonomy.

Indeed, no nonsensical centralized system may be implemented beyond the mandatory connection and use system. Technological advances today allow for the secure operation of even very small WWTP's. For that reason, decentralized and semi-decentralized concepts have gained increasingly in importance in designs for wastewater disposal.

The *costs of wastewater* disposal basically need to be covered by the fees and tariffs paid by private and commercial connected parties. Therefore, mandatory connection to and use of the public water supply and wastewater disposal is generally necessary.

According to surveys by the Association for Wastewater Technology and the Federal Association of German Gas and Water Management, the average total cost for wastewater disposal in 1996 amounted to € 108 per inhabitant per year. In the newly-

formed German states, in comparison to the old German states, there was an € 18 lower charge per inhabitant per year. The reason for this is that, despite higher average wastewater fees, water consumption in the newly-formed German states is lower than in former West Germany. For initial investments in WWTP's, states offer much support to municipalities by means of subsidies in varying amounts.
The distribution of cost types (see Figure 6) for wastewater disposal, as the basis for calculating disposal fees, varies with the regional peculiarities in the respective municipal disposal areas. In 1998, on average, amortisation accounted for 27% of costs, interest payments for 24%, personnel for 15%, the cost of electricity and materials accounted for 14%, waste disposal took up 4%, and the rest went to "miscellaneous expenses".

Water tariffs and wastewater fees

In a densely-populated industrial nation like Germany, the reliability and quality of a water supply system and of water protection is extremely important. Germany's level of technology and logistics is comparatively high; however, so are the costs, which are largely paid by the consumers by means of water tariffs and wastewater fees (full cost recovery).

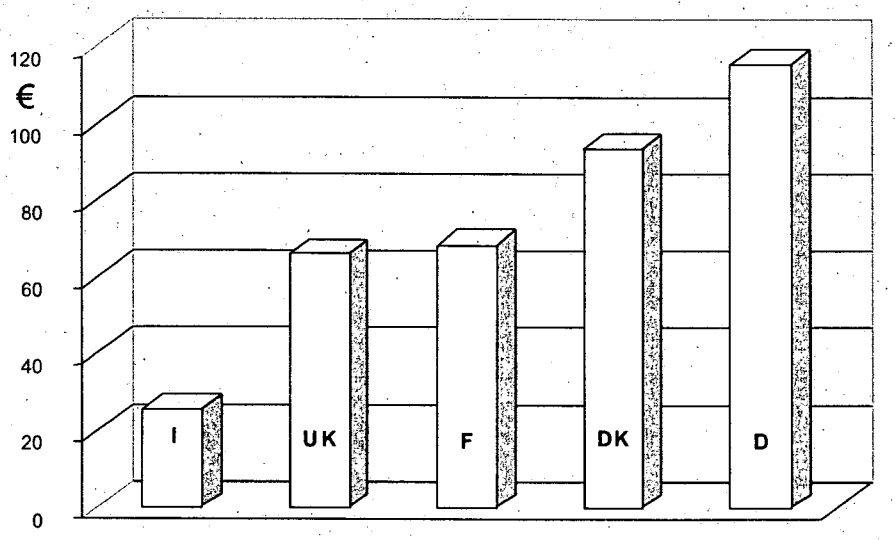

Figure 8: International comparison of wastewater treatment fees 1998 (per inhabitant per year) [6, 12]

In the former GDR, the wastewater treatment facilities were in a deplorable condition; in many places, WWTP's were non-existent. The water prices in the socialist planned economy didn't even come close to covering the costs of water treatment.

After German reunification, the systems needed to be repaired and newly built in as short of a time as possible. While the costs could be somewhat cushioned by state subsidies, etc.; primarily industry and the population connected to the systems had to bear the drastically increased water prices, including capital and operational expenses. This led to protest and political problems in many places.

There were similar problems also in several municipalities in western and northern Germany. Brought on by a few undesirable developments or extremely high costs, due to the rural structure and unfavourable conditions (construction grounds, topography, small receiving waters), doubts arose concerning the fairness of prices.

continuation of Water tariffs and wastewater fees

The solution to such problems and the transformation that was achieved in the ecological remediation of the former GDR can serve as a model for many nations world-wide which are currently struggling with the same basic problems in the water sector.

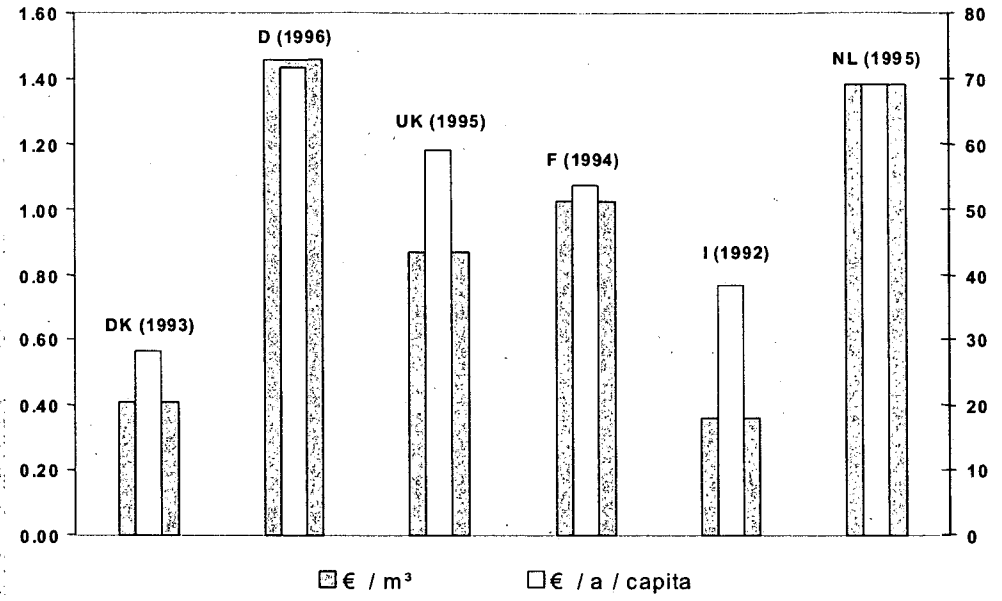

Figure 9: International comparison of the water prices 1998 [13]

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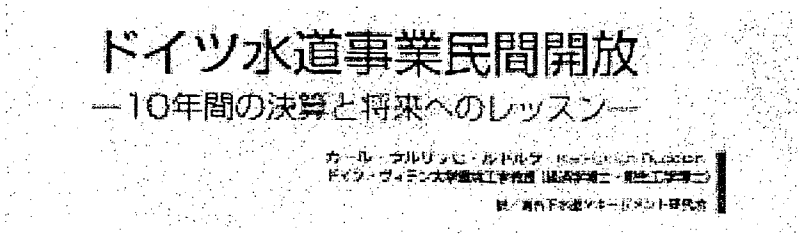
[1] 

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IMPACTS OF FOOD WASTE DISPOSERS ON SEWAGE SYSTEMS

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ABSTRACT

A variety of opinions concerning the introduction of Food Waste Disposers (FWDs) have been presented. However, many of these views are not based on objective grounds, as FWDs have rarely been employed in Japan. The MLIT, the Hokkaido government, and the town of Utanobori carried out a cooperative public trial. Prior to the trial, the town installed disposers in private homes in the sewered areas of the town, beginning in 1999. FWDs were first installed in 10% of the homes each year until 40% of the homes had disposers. The trial was carried out from the year 2000 to evaluate the impact of the introduction of FWDs

We investigated, among other issues, the amount of garbage generated, the quantity and quality of wastewater generated, and the condition of the sewer pipes and the wastewater treatment plant following the introduction of FWDs. This investigation was conducted by means of a case study on the introduction of FWDs in the town of Utanobori in Hokkaido.

KEYWORDS

Food Waste Disposers (FWDs), Wastewater pollution load, Sewage pipe, Wastewater treatment plant

INTRODUCTION

A variety of opinions concerning the introduction of FWDs have been presented. However, many of these views are not based on objective grounds, as disposers have rarely been employed in Japan. The MLIT, the Hokkaido government, and the town of Utanobori carried out a cooperative public trial. Prior to the trial, the town installed disposers in private homes in the sewered part of the town, beginning in 1999. FWDs were installed in 10% of the homes each year, until this figure rose to 40%.

The trial was then conducted, starting from the year 2000. Its purpose was to evaluate the impact of the introduction of the FWDs in terms of several parameters.

The survey is still in progress, and the final report will be released in May 2004. This will be an interim report based on the results obtained so far.

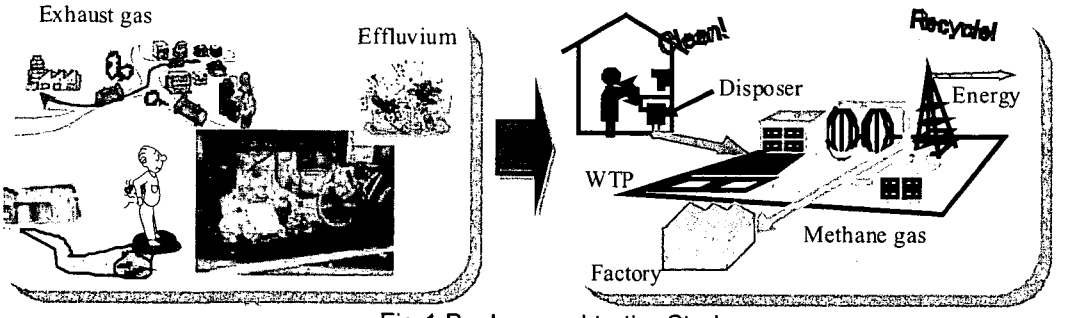

Fig.1 Background to the Study

METHODS

Outline of Utanobori-cho

Utanobori-cho is a farming village in the northern part of Hokkaido. The weather conditions in this town are severe, as it is a heavy snowfall area(Fig.2).

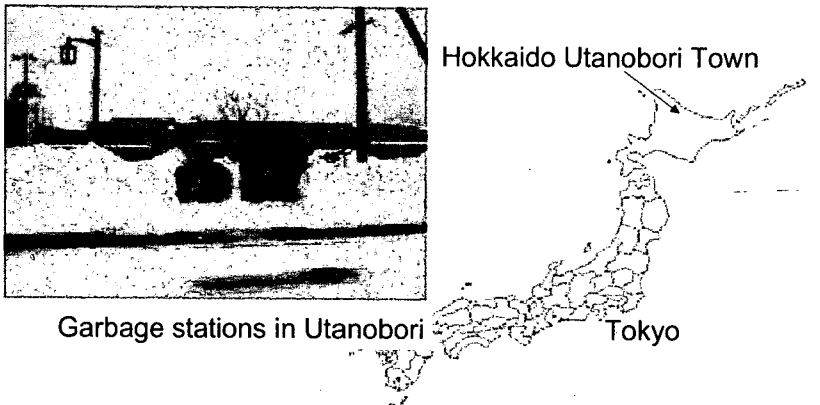

Fig.2 Hokkaido Utanobori Town

The population of the town is 2,519. Of this, the sewered population is 1,986, which is approximately 80% of the total population. The garbage collection system in Utanobori-cho is a separate sewer system.

Sewage Systems of Utanobori-cho

The method followed in processing the water in the wastewater treatment plant is the oxidation ditch process. The system is designed to handle a maximum wastewater flow of 1,260 m^3/day. The average wastewater flow in March 2003 was 736 m^3/day.

The total length of sewage pipes in the sewered area is 22,912 m, and several of these pipes are unplasticized polyvinyl chloride pipes of a 200 mm caliber.

Installation of FWDs

In Utanobori-cho, FWDs were installed in 300 homes (639 persons), mainly apartments in a housing complex. This was done between August 1999 and March 2003. The ratio of installed FWDs to the number of residents in March 2003 was 36%.

1. Wastewater pollution load due to the use of FWDs

1) Amount of garbage turned over to FWDs

This investigation measured the amount of garbage that was being sent to garbage stations before and after the introduction of FWDs Thus, the amount of garbage being disposed of through FWDs was determined, and this garbage was weighed. Further, the garbage that was mixed with burnable waste was segregated, because in Utanobori-cho,

garbage was turned over to the garbage station as burnable waste. Further, kinds of garbage in which a decline was observed following the introduction of FWDs were examined. The investigation was carried out a total of 18 times, once every 2-3 months between July 2000 and January 2003.

2) Increase in load due to the use of FWDs

The analysis of the FWD drain revealed that it had been made artificially, by using the garbage that had been collected from 10 houses in Utanobori-cho in which FWDs had been set up. For the one week during which the investigation was conducted, the garbage collected in the homes that were part of the investigation was preserved without the use of FWDs and was collected daily. The investigation was conducted a total of 15 times between June 2000 and July 2003.

2. Effect on the Sewer Pipes

1) Investigation of the condition of sewer pipes

It was predicted that pulverizing garbage using FWDs and allowing it to flow into the sewer system would increase the deposition of material in the sewer pipes. The condition of the sewer pipes was examined using a TV camera, both before the installation of FWDs in July 1999 and in September 2003 after they were introduced.

2) Composition of the deposited material

Deposit was gathered from sewer pipes in the districts in which FWDs had been introduced, and its composition was investigated.

3. Effect on Wastewater Treatment Plant

It was predicted that the rise in the influent load at the wastewater treatment plant would worsen the quality of the effluent water and increase the production of sewage sludge.

RESULTS

1. Wastewater Pollution Load due to the Use of FWDs

1) The amount of garbage sent to FWDs

Table 1 shows the results of a survey of the quantity of burnable garbage in a housing estate in Utanobori-cho, where FWDs were installed in August 2001. It shows that the introduction of the disposers reduced the amount of kitchen garbage by almost half.

Table 1. Reduction in the Quantity of Burnable Garbage

Period		Disposer	Burnable garbage (g/cap/day)		
				Rate	Weight
2000	Jul	Before installation	387.3	46.9%	182
	Sep		355.8	39.1%	139
	Nov		405.1	69.8%	283
	Feb		350.0	65.5%	229
2001	May		443.2	46.7%	207
	Aug	After installation	332.7	27.5%	91
	Oct		379.8	24.8%	94
	Jun		300.1	39.1%	117

Following the installation of FWDs, an approximate decrease of 100g/cap/day was observed in the garbage handled by the garbage station. In other words, the garbage turned over to FWDs is presumed to be about 100 g/cap/day. Following the installation of FWDs, a significant decrease in fruit and vegetable garbage was recorded.

2) Increase in load due to the use of FWDs

The results on the quality of the water in the disposer drain, expressed in terms of loading dose per 100 g of garbage, is shown in Table 2.

Table 2. Increase in the Pollutant Load Per Unit Production by Disposer Drainage

	SS	BOD	COD_{Mn}	T-N	T-P	n-Hex	Cl^-
Design manual	45	58	27	11	1.3	—	—
Our study	8.23	11.3	5.47	0.73	0.11	1.75	0.33
	(+18%)	(+19%)	(+20%)	(+7%)	(+8%)	(—)	(—)

The pollution loads per 100g of garbage for various pollutants are given as follows—SS: 8.2 g; BOD: 11.3 g; COD_{Mn}: 5.5 g; TN: 0.73 g; TP: 0.11 g; Cl^-: 0.33 g, and n-Hex: 1.75 g. Further, the increase in the daily per capita load was found to be 19% for SS and 21% for COD.

2. Influence on the Sewer Pipe

1) Investigation of the condition of the sewer pipe

Photo 1 and Photo 2 show images of the pipe before and after the installation of the disposers. Although the main pipe had not been cleaned even once since it first became functional in 1991, it was almost completely free of deposited material before the installation of the disposers. However, when the interior of the pipe was photographed 12 months after the installation of the disposers, a large amount of deposited material could be seen at the bottom. Further, a significant amount of material had been deposited in the part where the inclination of the sewer pipe was gradual (Table 3).

Photo 1 (before installation, July, 1999)

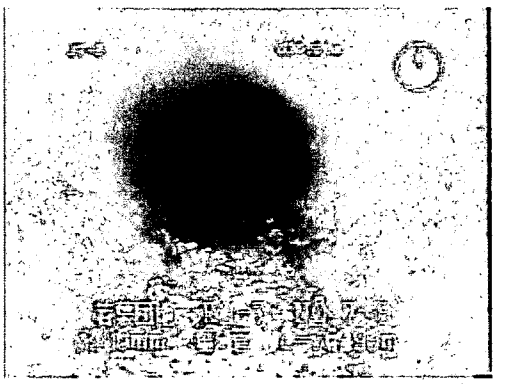

Photo 2 (after installation, August 2000)

2) Composition of deposited material

The deposited material comprised eggshells and shells of shellfish. These solid materials tended to be deposited at locations where the gradient of the pipe was gentle. These results suggest that following the installation of disposers, it is necessary to inspect pipes more frequently and clean them more often as necessary.

Table 3. Relationship between the inclination of the sewer pipe and the amount of deposit

Inclination (‰)	Length of the sewer pipe according to inclination (m)	Amount of deposit (cm^3)	Rate of deposit (%)
10≦	81	809	1.9
7.5≦<10	194	2,561	6.0
5≦<7.5	314	2,306	5.4
2.5≦<5	208	3,519	8.2
0≦<2.5	53	1,064	2.5
≦<0	46	32,592	76.1
Total	896	42,851	100

3. Effect on Wastewater Treatment Plant

Fig. 3 showed the change in the influent water quality and the processing water from 1991 to 2001. No clear change was observed in the quality of the influent and processing water before and after the introduction of FWDs.

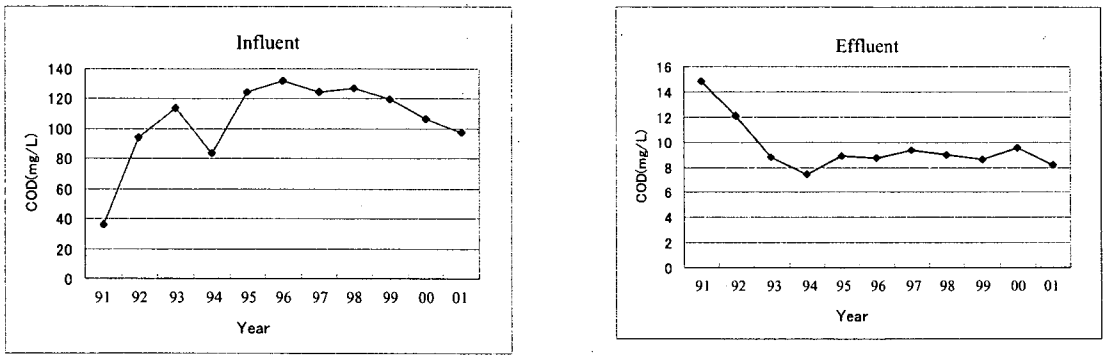

Fig. 3 Annual Variations in the Influent and Effluent Water

CONCLUSIONS

This study investigated, among other issues, the amount of garbage generated, the quantity and quality of wastewater generated, and the condition of the sewer pipes and wastewater treatment plants following the introduction of FWDs. This investigation was conducted by means of a case study on the introduction of the FWDs in the town of Utanobori in Hokkaido, where the FWDs was used in 36% of the homes in the sewered area.

This report estimated the per unit increase in pollution load that resulted from the use of the garbage grinder in the town of Utanobori. The results are as follows:

1) The amount of burnable garbage by weight was halved.
2) The amount of garbage processed with the FWDs was 100g/cap/day, which is about half the amount of garbage put out per person per day.
3) The pollution loads of various pollutants per 100 g of garbage were as follows.SS:8.2 g; BOD: 11.3 g; COD_{Mn}: 5.5 g; TN: 0.73 g; TP: 0.11 g; Cl^-: 0.33 g, and n-Hex: 1.75 g.
4) The amount of deposit in the sewer pipe increased following installation of the FWDs.
8) No clear change in the quality of the influent and processing water was observed before and after the introduction of the disposer.

Disposers were introduced as part of the wastewater treatment system for the first time in Japan in the town of Utanobori. Therefore, in this sense, the results obtained were valuable. The author hopes that this report will contribute to debates on the evaluation of the impact of the introduction of disposers.

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THE SIXTH RESEARCH FRAMEWORK PROGRAMME OF THE EUROPEAN UNION (2002-2006)

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ABSTRACT

A short overview of the basic features of the 6th EU Framework Programme for Research and Technological Development (FP6) is presented. FP6 is the frame for the EU activities in the field of science, research and innovation. With a budget of 17.5 billion Euro for the years 2002 – 2006 it represents about 5 percent of the overall expenditure on RTD in EU Member States. The main objective is to contribute to the creation of the European Research Area (ERA) by improving integration and coordination of research in Europe which is so far largely fragmented.

KEYWORDS

European research funding, European research area, Framework programme for research and technological development.

OBJECTIVE

FP6 aims to contribute to the creation of a true "European Research Area" (ERA). ERA is a vision for the future of research in Europe, an internal market for science and technology. It fosters scientific excellence, competitiveness and innovation through the promotion of better co-operation and coordination between relevant actors at all levels. Economic growth increasingly depends on research, and many of the present and foreseeable challenges for industry and society can no longer be solved at national level alone. At their summit in Lisbon in March 2000, heads of state and governments called for better leveraging of European research efforts through the creation of ERA. The FP is the financial instrument that will help make the European Research Area a reality.

BACKGROUND

The European Union (EU) has been conducting a policy of research and technological development based on multiannual framework programmes since 1984. The sixth framework programme is now in force and like its predecessors constitutes a useful instrument which exerts a significant impact on research activities in the Member States.

To exploit this potential to the full, however, a broader approach is necessary, requiring the creation of a real European Research Area , the goal of which is to create an arena to

promote the development of Europe's capacity to become one of the driving forces for research worldwide.

The European Research Area (ERA) is the cornerstone of the sixth framework programme. By improving greater cooperation between the various economic, social and scientific players, the ERA promotes scientific excellence, competitiveness and innovation.

INSTRUMENTS

The new framework programme aims to introduce two new instruments, networks of excellence and integrated projects.

- networks of excellence aim at progressively integrating the activities of partners networked through "virtual" centres of excellence,
- integrated projects are substantial in size and aim at constituting a critical mass in research activities focusing on clearly defined scientific and technological objectives.

In parallel, there are plans to use an instrument provided for in the Treaty but so far never deployed: the EU will participate in research programmes undertaken by several Member States.

STRUCTURE AND LINES OF ACTION

The sixth framework programme comprises five specific programmes:

- integrating and strengthening the European Research Area, including the thematic priorities;
- structuring the European Research Area;
- the activities of the Joint Research Centre (JRC);
- nuclear energy;
- the activities of the Joint Research Centre (Euratom).

The total budget for the sixth framework programme is 17.5 billion, 16.270 billion of which is for the European Community (EC) part and 1.230 million for the Euratom part. The framework programme will last for four years from 1 January 2003 to 31 December 2006.

A) <u>Integrating and reinforcing the European Research Area (thematic priorities). Budget: 13.345 billion</u>

1) Life sciences, genomics and biotechnology for health: Budget: 2.255 billion
   - Objective: to help Europe exploit breakthroughs achieved in decoding the genomes of living organisms, particularly for the benefit of public health and to increase the competitiveness of the European biotechnology industry.

2) Information society technologies: Budget: 3.625 billion
   - Objective: to stimulate the development of both hardware and software technologies and applications to allow European citizens the possibility of benefiting fully from the development of the knowledge-based society.

3) Nanotechnologies, knowledge-based multifunctional materials, new production processes: Budget: 1.300 billion

Objective: human resources development (Marie Curie fellowships) through the promotion of transnational mobility for training purposes or the transfer of knowledge to help make Europe more attractive to third country researchers.

3) Research infrastructures: Budget: EUR 655 million
Objective: to establish a fabric of research infrastructures in Europe which is more accessible.

4) Science and society: Budget: EUR 80 million
Objective: to encourage the development of harmonious relations between science and society as well as contributing to critical thinking on ethical questions, the precautionary principle , women and science, etc.

C) Strengthening the foundations of the European Research Area: Budget: EUR 320 million

The activities carried out under this heading are intended to step up coordination and to support the coherent development of research and innovation-stimulation policies and activities in Europe.

1) Coordination of national activities
Objective: to coordinate activities in areas such as health, biotechnology, the environment and energy.

2) European coordination
Objective: to set up initiatives under the aegis of scientific organisations such as COST (Cooperation in the field of scientific and technical research), ESO (European Southern Observatory), EMBL (European Molecular Biology Laboratory), etc. (see "international cooperation").

IMPLEMENTATION OF THE PROGRAMME

A) Participation

Any legal entity, i.e. any natural or legal person established in accordance with national, international or Community legislation may apply for and receive support. In other words, universities, international organisations, research institutes, SMEs and large companies may apply for financial support.

Up until now, it was impossible for a team of researchers from the candidate countries to coordinate a project unless they were partnered with researchers from the EU, but now these candidate countries are treated in the same way as the Member States.

B) Call for proposals

Projects must respond to a specific call for proposals. Research teams and consortia wishing to put forward a proposal in response to a call normally have at least three months to draw up and submit their file.

C) Information sources

In order to guarantee equality of access and fair treatment to all applicants, calls for proposals are published in the Official Journal of the European Communities and on

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the Commission Internet pages designed for this purpose. In parallel, the CORDIS server and the RTD info magazine also provide information.

At national level, there are networks of contact points to supply information on the framework programme for research. The national authorities can assist applicants who have no experience in applying for financial support. The national contact points (NCPs) are independent, decentralised help desks found in the Member States, the acceding countries and other partner countries.

D) Selection of projects

As far as is possible, project selection will comprise two phases. Participants will first be invited to submit a summary of their proposal. Subsequently, if their application following the initial selection procedure is accepted, they will be invited to submit a detailed proposal.

E) International cooperation

Research activities may be pooled in other European cooperation contexts, such as COST (Cooperation in the field of scientific and technical research of activities of public interest financed nationally in Europe and coordinated with the support of the EU) and EUREKA (an extra-Community programme for technological research and development based on mixed financing of activities).

F) Financing

The Commission contributes financially to the work of the research projects selected. Financial assistance is provided as follows:

1) Networks of excellence. The Commission finances:

   - areas of thematic priority;
   - supporting policies and anticipating scientific and technological needs.

   Funding: grant for integration, i.e. a maximum of 25% of the value of the capacities and resources which the participants propose to contribute as a fixed amount.

2) Integrated projects. The Commission finances:

   - priority thematic areas;
   - supporting policies and anticipating scientific and technological needs.

   Funding: a grant which totals a maximum of 50% of the budget for research, 35% for demonstration and 100% for certain other activities such as researcher training and consortium management.

3) Specific targeted research or innovation projects. The Commission finances:

   - priority thematic areas;
   - supporting policies and anticipating scientific and technological needs;
   - specific measures in support of international cooperation;
   - promoting the interaction between research and innovation;
   - the development of harmonious relations between science and society.

Funding: a grant totalling a maximum of 50% of the budget.

4) Participation in programmes implemented by several Member States. The Commission finances:

   - all the activities of the sixth framework programme.

   Funding: (still to be determined).

5) Specific research projects for small and medium-sized enterprises (SMEs). The Commission finances:

   - specific research projects for SMEs.

   Funding: a grant totalling a maximum of 50% of the budget.

6) Actions to promote and develop human resources and mobility. The Commission finances:

   - the development of human resources and promotion of mobility.

   Funding: a grant totalling a maximum of 100% of the budget, possibly in the form of a lump sum payment.

7) Coordination actions. The Commission finances:

   - all the activities of the sixth framework programme.

   Funding: a grant totalling a maximum of 100% of the budget.

8) Specific support actions. The Commission finances:

   - all the activities of the sixth framework programme.

   Funding: a grant totalling a maximum of 100% of the budget, possibly in the form of a lump sum payment.

9) Integrated infrastructure initiatives. The Commission finances:

   - support for research infrastructure.

   Funding: according to the nature of the activities, a grant to the budget totalling between 50 and 100% of that budget.

10) Direct actions. The Commission finances:

   - non-nuclear activities of the Joint Research Centre (JRC).

   Funding: 100% of the budget.

WORK PROGRAMME

Work programme 1.1.6.3 Global Change and Ecosystems

Global Change and Ecosystems sub-priority is addressing seven areas relative to the issues of :

I. Impact and mechanisms of greenhouse gas emissions and atmospheric pollutants on climate, ozone depletion and carbon sinks
II. Water cycle, including soil-related aspects
III. Biodiversity and ecosystems
IV. Mechanisms of desertification and natural disasters
V. Strategies for sustainable land management, including coastal zones, agricultural land and forests
VI. Operational forecasting and modelling including global climatic change observation systems
VII. Complementary research

The topics of each of the areas are the subjects of the calls for proposals.

II. Water cycle, including soil-related aspects

The objective is to understand the mechanisms and assess the impact of global change, and in particular climate change, on the water cycle, water quality and availability, as well as soil functions and quality to provide the bases for management and technological tools for water systems, to mitigate the impacts. The research will focus on hydrology and climate processes, the ecological impacts of global change, soil functioning and water quality, integrated management strategies and mitigation technologies, and scenarios of water demand and availability.

Topics

II.1. Hydrology and climate processes
II.1.1 Climate modelling at cachment regional scale
II.1.2 Climate variability, floods and drougts

II.2. Ecological impact of global change, soil functioning and water quality
II.2.1 Impacts of global change on the ecology of surface water bodies
II.2.1.a Assessment of ecological impacts of global change on freshwater bodies, development of ecological indicators of ecosystem "health" and related remediations strategies
II.2.2 Water-soil system functioning and management
II.2.2.a River-soil-groundwater system functioning
II.2.2.b Soil-groundwater protection

II.3. Integrated management strategies and mitigation technologies
II.3.1 Integrated water management at catchment scale
II.3.1.a Twinning European / Third Countries river bassins
II.3.1.b Methodologies of Integrated Water Resource Management and Transboundary issues
II.3.2 Integrated urban water management and mitigation technologies
II.3.2.a Waste-water treatment for re-use
II.3.3 Management of scarce water resources and mitigation technologies
II.3.3.a Technologies for monitoring and mitigating the impact of water scarcity
II.3.3.b New approaches to water stress

II.4. Scenarios of water demand and availability
II.4.1 Water scenarios for Europe and for neighbouring countries

REFERENCE

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OCCURRENCE OF ESTROGEN-LIKE SUBSTANCES IN WASTEWATER IN JAPAN

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ABSTRACT

The field study was conducted at twenty WWTPs in Japan about following estrogens: estrone(E1); 17β-estradiol(E2); 17α-ethynylestradiol(EE2); estriol(E3); estrone-3-sulfate(E1 -S); β-estradiol 3-sulfate (E2-S); estriol 3-sulfate (E3-S); estrone β-D-glucuronide(E1-G); β-estradiol 17-(β-D)-glucuronide(E2-G); estriol 3- (β-D)-glucuronide(E3-G); β-estradiol 3-sulfate 17-glucuronide(E2-S&G); and estradiol 3,17-disulfate(E2-diS). The median concentrations of the estrogens ranged from ND to as high as >100 ng/L. In the influent samples, the concentration of E1, E2 and E3 are the same levels as those were previously reported. The conjugated estrogens are higher than those of the free estrogens. The reduction of the free estrogens in WWTPs was good. The concentrations of a few conjugated estrogens (E1-S and E2-S) were declined in the WWTPs, while the levels of other conjugated estrogens (E3-S, E1-G, E2-G, E3-G, E2-S&G and E2-diS) were increased in the WWTPs. Morepver, the other field study was conducted at twelve WWTPs in Japan about following substances: nonylphenol(NP); nonylphenol ethoxylates(NPEOs); and nonylphenoxy acetic acids(NPECs). The concentrations of NP and Long-EO-chain NPEOs were declined in WWTPs while the levels of short –EO-chain NPECs were increased in the WWTPs.

KEYWORDS

Endocrine disruptors, 17β-estradiol, estrone, estrogen, estrogen conjugates, nonylphenol, nonylpehol ethoxylate, nonylphenoxy acetic acid.

INTRODUCTION

In recent years a new problem has emerged in our water environment, namely, endocrine disruptors (EDs) that may adversely affect the reproductive functions of human beings and wildlife. In Japan the EDs issue has arisen since the book "OUR STOLEN FUTURE (Colborn et al., 1996)" was introduced in 1997. Contamination of water with EDs poses new and potential environmental (and social) problems. The Japan Environmental Agency (JEA) published strategic programs on environmental endocrine disruptors (SPEED '98), in which basic policies and specific approaches to the problem are documented (JEA, 1998). In this document, the JEA listed more than 70 chemicals that are suspected to cause abnormalities in animals at extremely low levels. The Ministry of Land, Infrastructure and Transport (MLIT) of Japan has decided to grasp EDs conditions in the water environment conducting extensive studies with major rivers and WWTPs (MLIT, 2001a). Among over 70 suspected substances, the MLIT selected 27 compounds for the river studies and 25 substances for the WWTPs studies, based on the annual production of the chemicals and the levels detected in the environment. The MLIT particularly concerned female hormones originating from humans

and animals. The study by the MLIT, thus far, found that estrogen represented by 17β-estradiol (E2) exists in river water and wastewater (including treated wastewater) at significant levels (MLIT, 2001a; Tanaka et al., 2001b, 2003).

Analytical methods currently available for EDs are limited their applications to certain chemicals. The method for the analysis of E2 in the early stage of the MLIT survey had been based on enzyme linked immunosorbent assay (ELISA), which can detect E2 as low as 0.2 ng/L. However, due to the potential "cross-reaction" problem, ELISA is limited in its applications to certain conditions when it is applied to domestic wastewaters. Recently, estrone (E1) has emerged as concerned EDs in water environment (MLIT, 2001b; Goda *et al.*, 2001), and many other estrogen-like chemicals appear to have estrogenic effects on fish. Furthermore, naturally occurring estrogens (e.g., E1 and E2) and nonylphenol (NP) tend to have higher estrogenic potentials than other synthetic, industrial chemicals (Yakou *et al.*, 1999; Tanaka *et al.*, 2001b). Although E2 and 17α-ethynylestradiol (EE2) can be analyzed simultaneously using the GC/MS method (Huang *et al.*, 2001), this method is rather cumbersome requiring a derivatization process. PWRI refined the analytical method developed by Komori *et al.* (2001) for the analysis of specific estrogens (i.e., E2, E1, and EE2) present in wastewater. This method uses a LC/MS/MS, but the derivatization process is not required. Estrogens are excreted by male as well as female animals. Prior to excretion, most estrogens are hydroxylated and conjugated to glucuronides, sulfates, and acetates. Because very few analytical methods (Ternes *et al.*, 1999a; Belfroid *et al.*, 1999) are capable of analyzing estrogenic compounds, relatively little work has been directed toward investigating impacts and occurrence of estrogens in water environment. PWRI refined an analytical procedure (Komori *et al.* 2003) that allows routine analysis of estrogens and their conjugates (i.e., glucuronides and sulfates conjugates) in wastewater based on the method by Komori *et al.* (2002),

On the other hand, nonylphenol (NP) is known to be byproduct of nonylphenol ethoxylates (NPEOs) which are used as detergent for industrial use (Ahel *et al.*, 1994). It is important that not only NP but also NPEOs and their related substances are analyzed when behavior of NP in wastewater treatment process is surveyed. NPEOs are biodegraded to shorter-EO-chain NPEOs or NPECs under aerobic condition, and then biodegraded to NP under anaerobic condition. NP is a suspected endocrine disrupting chemical. Moreover, shorter-EO-chain NPEO has higher toxicity than longer EO chain NPEO (Comber *et al.*, 1993). PWRI developed analytical methods (Yasojima *et al.*, 2002a, 2002b) which can analyze NP, NPEO (EO chain length 1-15) and NPEC (EO chain length 1-10) in wastewater.

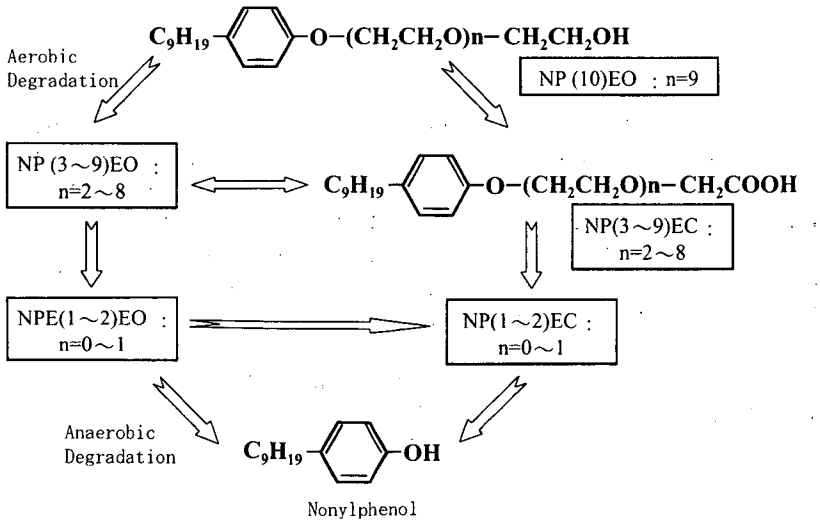

Figure 1 Degradation pathway of NP and its related substances

As mentioned above, result of YES (Yeast Estrogen Screening Test) shows that estrogens (E1, E2), EE2 and NP has high estrogenicity. This paper describes results of field study on estrogen, conjugated estrogens, NP and its related substances in wastewater treatment process.

METHOD

Field survey of estrogens and their conjugates

The field surveys were conducted at twenty WWTPs where influent and secondary effluent were collected for the analysis of estrogens and their conjugates (i.e., E1, E2, EE2, estriol (E3), estrone-3-sulfate (E1-S); β-estradiol 3-sulfate (E2-S); estriol 3-sulfate (E3-S); estrone β-D-glucuronide (E1-G); β-estradiol 17-(β-D)-glucuronide (E2-G); estriol 3-(β-D)-glucuronide (E3-G); β-estradiol 3-sulfate 17-glucuronide (E2-S&G); and estradiol 3,17-disulfate (E2-diS) . The capacities of these WWTPs range from 12,000 to 680,000 m^3/day. Thirteen of them apply a conventional activated sludge process. Three WWTPs employ an anaerobic-oxic activated sludge proceee (A/O process). Other WWTPs adapted various combined process: i.e., a conventional activated sludge process with rapid filtration; a conventional activated sludge process with rapid filtration and carbon adsorption; or an anaerobic-anoxic-oxic process (A_2/O process) with rapid filtration and step aeration process. Grab samples were collected at WWTP sites. One gram of L-ascorbic acid was added to 1 litter of sample to prevent oxidation. All samples were collected in one-litter glass bottles, refrigerated, and transported to the laboratory within one day. Concentrations of estrogens and estrogen conjugates were measured by the method of Komori *et al.*,(2003).

Field survey of nonylphenol (NP) and its related substances

12 WWTPs were selected for the survey of nonylphenol and its related substances (i.e., NP, NPnEO (n=1-15), NPnEC (n=1-10)). All the WWTPs applied a conventional activated sludge process. The capacities of these WWTPs range from 17,300 to 168,000 m^3/day. Grab samples were taken from the influent and the secondary effluent. One gram of L-ascorbic acid was added to 1 litter of sample to prevent oxidation. All samples were collected in one-litter glass bottles, refrigerated, and transported to the laboratory within one day. Concentrations of NP and NPEOs were measured by HPLC. HPLC was performed by the method of Komori *et al.*, (2002). Concentrations of NPnECs were measured by LC/MS/MS. LC/MS/MS was performed by the method of Yasojima *et al* (2002b).

RESULT AND DISCUSSION

Field survey of estrogens and their conjugates

The measured concentrations of the target compounds in wastewater are presented in Table 1. In the WWTP influent, we found: 10 - 57 ng/l (median, 24 ng/l) of E1; ND - 21 ng/l (median, 5.7 ng/l) of E2; 27 – 220 ng/l (median, 110 ng/l) of E3; 12 - 170 ng/l (median, 42 ng/l) of E1-S; 26 - 410 ng/l (median, 110 ng/l) of E2-S; 6.5 - 79 ng/l (median, 22 ng/l) of E3-S; ND - 88 ng/l (median, 11 ng/l) of E1-G; 5.3 - 100 ng/l (median, 18 ng/l) of E2-G; 4.1 - 73 ng/l (median, 22 ng/l) of E3-G; 0.8 - 38 ng/l (median, 5.5 ng/l) of E2-S&G; and 21 - 670 ng/l (median, 77 ng/l) of E2-diS. In the secondary effluent, we observed: ND - 180 ng/l (median, 12 ng/l) of E1; ND - 11 ng/l (median, ND) of E2; ND - 5.8 ng/l (median, 1.5 ng/l) of E3; 7.5 - 34 ng/l (median, 13 ng/l) of E1-S; 27 - 94 ng/l (median, 52 ng/l) of E2-S; 37 - 160 ng/l (median, 69 ng/l) of E3-S; 34 - 140 ng/l (median, 74 ng/l) of E1-G; 47 - 210 ng/l (median, 91 ng/l) of E2-G; 37 - 150 ng/l (median, 72 ng/l) of E3-G; 3.7 - 17 ng/l (median, 8.9 ng/l) of E2-S&G; and 160 - 1500 ng/l (median, 360 ng/l) of E2-diS. EE2 was not detected in any of the samples analyzed (including WWTP influent and secondary effluent). The concentrations

of E1, E2, and E3 were the same levels as those reported in the literature (Tanaka *et al.*, 2003; MLIT, 2001b; Huang *et al.*, 2001; Komori et al., 2001; Ternes *et al.*, 1999a and Belfroid et al., 1999). Reductions of E2 and E3 (free, unconjugated estrogens) in the WWTPs were very good having nearly 100% and 98% reductions (calculated using median value), respectively. Reduction of E1 is 47%, which was considerably smaller than those of E2 and E3. This observation is consistent with Ternes *et al.* (1999b) who reported that the degradation rate of E1 is smaller than that of E2. Belfroid *et al.* (1999) reported that hormone-glucuronides exist generally below their detection limits in the effluent of WWTPs. However, the concentrations of the conjugated estrogens that we measured were higher than those of the unconjugated (free) estrogens in spite of the lower recovery ratios. The average concentrations of E1-S and E2-S (conjugated estrogens) were reduced in the WWTPs, but other conjugated estrogens (i.e., E3-S, E1-G, E2-G, E3-G, E2-S&G and E2-diS) were increased. The removal efficiencies of E1-S and E2-S (conjugated estrogens) were approximately 68% and 51%, respectively.

Table 1. Concentrations of Selected Estrogens Detected in Wastewater Samples from Twenty WWTPs (ng/l)

		min	25%	median	75%	max
influent	E1	10	17	24	29	57
	E2	ND (<0.5)	1.9	5.7	8.6	21
	EE2	ND (<1.2)	ND	ND	ND	ND
	E3	27	52	110	130	220
	E1-S	12	21	42	78	170
	E2-S	26	52	110	220	410
	E3-S	6.5	12	22	41	79
	E1-G	ND (<1.3)	5.2	11	24	88
	E2-G	5.3	12	18	31	100
	E3-G	4.1	11	22	38	73
	E2-S&G	0.8	2.2	5.5	12	38
	E2-diS	21	41	77	120	670
effluent	E1	ND (<0.8)	3.1	12	46	180
	E2	ND (<0.5)	ND	ND	ND	11
	EE2	ND (<1.2)	ND	ND	ND	ND
	E3	ND (<1.4)	0.9	1.5	2	5.8
	E1-S	7.5	8.8	13	17	34
	E2-S	27	44	52	56	94
	E3-S	37	56	69	77	160
	E1-G	34	58	74	82	140
	E2-G	47	76	91	110	210
	E3-G	37	55	72	90	150
	E2-S&G	3.7	6.1	8.9	9.6	17
	E2-diS	160	240	360	510	1500

ND : Not detected (less than detection limit)

Field survey of nonylphenol (NP) and its related substances

The measured concentrations of the target compounds in wastewater are presented in. In the secondary effluent, we observed: 0.10-1.0μg/L (median, 0.20μg/L) of NP. Table 2 and Figure 2. In the WWTP influent, we found: 0.50-20μg/L (median, 1.7μg/L) of NP.
Regarding NP related substances, in the WWTP influent, NPEOs from NP1EO to NP15EO (mainly NP6EO-NO8EO) were detected but there were hardly any NPECs. In the secondary effluent, there were hardly any NPEO whose EO chain length is more than 5 and NPECs from NP1EC to NP4EC were detected. These results indicate that reduction of long-chain-NPEOs (EO chain length is more than 5) in STPs were very good but reduction of short-chain- NPEOs were small. Moreover, it was indicated that NPECs were produced in aerobic wastewater treatment process and degradation rate of long-chain-NPEC (EO chain length is more than 5) is large but degradation rate of short-chain NPEC is smaller.

Table 2 Results of NP and its relates substances in WWTPs

		Influent				Secondary Effluent			
		Detection limit	min	median	max	Detection limit	min	median	max
Nonylphenol	NP	0.10	0.50	1.7	20	0.10	0.10	0.20	1.0
Nonylphenol Ethoxylate	NP1EO	0.04	0.82	2.1	17	0.04	0.04	0.26	0.49
	NP2EO	0.04	0.54	2.9	11	0.04	0.16	0.30	1.5
	NP3EO	0.06	1.2	4.5	14	0.06	0.07	0.14	0.81
	NP4EO	0.04	3.5	9.8	21	0.04	0.60	0.98	1.7
	NP5EO	0.05	2.0	7.3	23	0.05	N.D.	N.D.	0.08
	NP6EO	0.07	2.4	7.8	24	0.07	N.D.	N.D.	0.14
	NP7EO	0.05	2.4	7.9	23	0.05	N.D.	N.D.	0.14
	NP8EO	0.08	2.8	7.5	24	0.08	N.D.	N.D.	N.D.
	NP9EO	0.07	2.6	6.2	20	0.07	N.D.	N.D.	N.D.
	NP10EO	0.15	2.0	5.2	18	0.15	N.D.	N.D.	N.D.
	NP11EO	0.07	1.1	3.9	15	0.07	N.D.	N.D.	N.D.
	NP12EO	0.14	0.73	2.7	12	0.14	N.D.	N.D.	N.D.
	NP13EO	0.18	0.23	1.7	11	0.18	N.D.	N.D.	N.D.
	NP14EO	0.16	0.35	1.2	6.7	0.16	N.D.	N.D.	N.D.
	NP15EO	0.23	0.34	1.5	3.4	0.23	N.D.	N.D.	N.D.
Nonylphenoxy Acetic Acid	NP1EC	0.002	0.085	0.15	0.78	0.002	0.35	1.2	3.4
	NP2EC	0.002	0.11	0.36	4.7	0.002	1.1	3.5	10
	NP3EC	0.002	0.098	0.20	2.5	0.002	0.51	1.2	4.4
	NP4EC	0.002	0.086	0.14	0.99	0.002	0.13	0.52	2.5
	NP5EC	0.002	0.088	0.14	0.88	0.002	0.065	0.24	1.2
	NP6EC	0.002	0.11	0.14	0.48	0.002	0.009	0.049	0.62
	NP7EC	0.002	0.054	0.13	0.50	0.002	0.006	0.019	0.31
	NP8EC	0.002	0.052	0.12	0.53	0.002	0.005	0.028	0.27
	NP9EC	0.002	0.055	0.11	0.46	0.002	N.D.	0.028	0.13
	NP10EC	0.002	0.057	0.11	0.45	0.002	N.D.	0.023	0.069

Unit: μg/l N.D.: non-detection

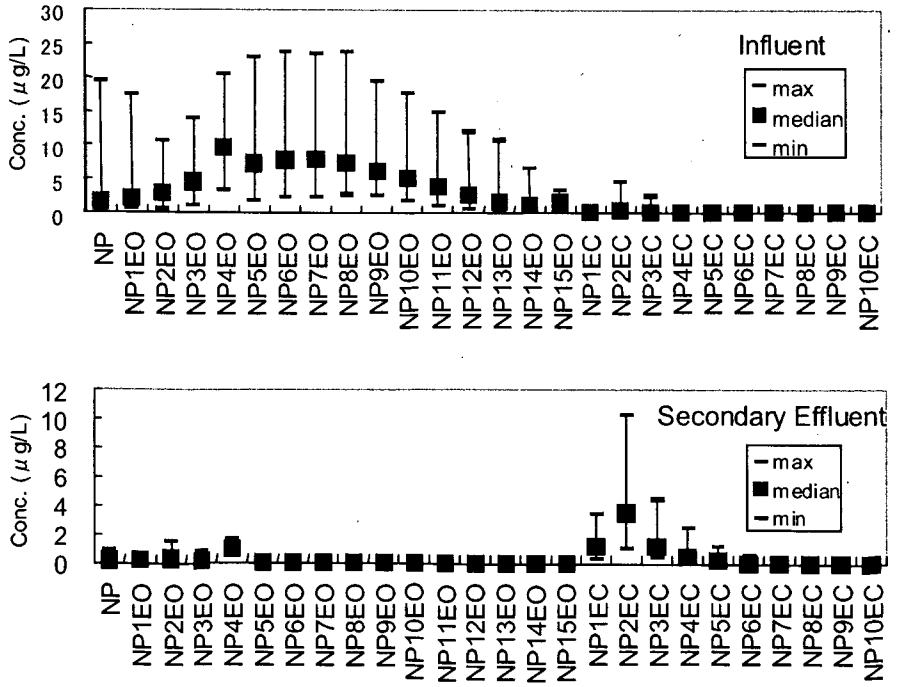

Figure 2. Change of NP and its related substances in WWTPs

In order to understand behavior of target compounds in wastewater treatment process, we focus on A STP of the 12 STPs as an example. The observed concentrations of target compounds in A STP are presented in Figure 3, Figure 4.

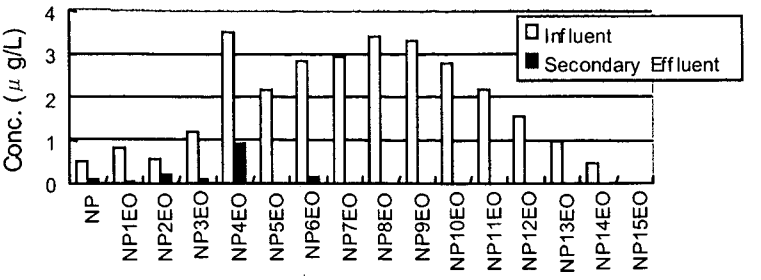

Figure 3 Change of NPEOs in A WWTP

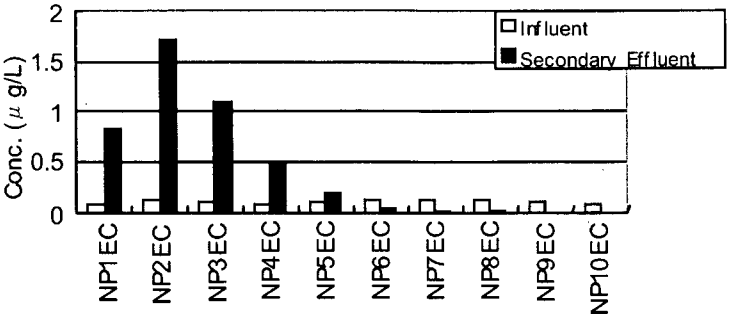

Figure 4 Change of NPECs in A WWTP

Regarding NPEOs, in the WWTP influent, NPEOs from NP1EO to NP14EO were detected and it is indicated that NPEOs were degraded easily in wastewater treatment because concentrations of NPEOs decreased drastically in the secondary effluent. It is unknown why values of NP4EO in both the influent and the secondary effluent were relatively large.
Regarding NPECs, in the WWTP influent, concentrations were below 0.1μg/L, but concentrations of NPECs increased during wastewater treatment. Concentration of NP2EC was largest and NPEC from NP1EC to NP5EC were observed in the secondary effluent. One possible explanation about accumulation of NPECs in wastewater treatment process is difference between degradation rate of NPEO and NPEC. On the other hand, it is indicated that long-EO-chain NPEO changed to short-EO-chain NPEO and further to NPEC because long-EO-chain NPEC were not produced. Concentrations of NP in the secondary effluent were smaller than those in the influent. It was not unclear whether NP was biodegraded or removed by adsorption to sludge because concentrations on/in sludge were not measured.

CONCLUSIONS

1) LC/MS/MS method by Komori *et al.*,(2003) was applied to the wastewater samples collected from twenty WWTPs. The concentrations (median) of estrogens and their conjugates in the WWTP influent range from non-detection (ND) to as high as >100 ng/L. In the influent samples, the concentrations of E1, E2 and E3 were the same levels as those were previous reported. Belfroid *et al.* (1999) reported that hormone-glucuronides exist generally below their detection limits in effluent of WWTPs. However, the concentrations of conjugated estrogens that we measured were higher than those of free estrogens.
2) The reduction of the free estrogens in the WWTPs was very good with approximately 100% and 98% for E2 and E3, respectively, while removal efficiency for E1 (47%) was less significant than E2 and E3, suggesting that the degradation rate of E1 was smaller than that

of E2 in the wastewater treatment processes. The concentrations of the conjugated estrogens (E1-S and E2-S) were declined in the WWTPs, while the levels of other conjugated estrogens (E3-S, E1-G, E2-G, E3-G, E2-S&G and E2-diS) were increased in the WWTPs.
3) HPLC method and LC/MS/MS method by Yasojima et al., (2002a, 2002b) were applied to the wastewater samoles from twelve WWTPs. The concentrations (median) of nonylpheol and its related substances in the WWTP influent range from non-detection (ND) to as high as >20μg/L. In the influent samples, the concentrations of NP were the same levels as those were previous reported.
4) The reduction of the long-EO-chain NPEOs in the WWTPs was very good with approximately 100%, respectively, while removal efficiency for short-EO-chain NPEOs was less significant than long-EO-chain NPEO, suggesting that the degradation rate of short-EO-chain NPEOs were smaller than those of long-EO-chain NPEO in the wastewater treatment processes. The concentrations of the NP were declined in the WWTPs, while the levels of short-EO-chain NPECs were increased in the WWTPs.

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FATE OF ENDOCRINE DISRUPTORS CONTAINED IN COMPOSTED SLUDGE AFTER LAND APPLICATION

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ABSTRACT

Many environmental problems caused by endocrine disruptors (EDs) are reported. Little is known about the fate of EDs accumulated in sewage sludge, and we carried out research to make clear the fate of EDs in composted sludge after it is applied to soil. Nonylphenol (NP) and 17β-estradiol (E2) were measured for leachate and soil. High concentrations of NP and E2 were detected in the leachate at the early stage, but they decreased rapidly. Also, high amount of NP and E2 contents in soil decreased significantly. Because the amount of the decrease of NP and E2 in the soil was much larger than the amount of NP and E2 in the leachate, there must be physicochemical or biological decomposition mechanism in the soil layer.

KEYWORDS

Endocrine Disruptors, Composted Sewage Sludge, Lysimeter.

INTRODUCTION

In recent years, there have been many reports on environmental problems caused by endocrine disruptors (EDs) discharged as trace-chemicals in many countries and regions. The Japanese Ministry of Construction carried out a national survey on the EDs pollution of river waters and treated wastewater in FY1998 (MOC, 1999). Some trace-chemicals suspected to be EDs were detected at almost all surveyed points showing relatively higher concentration in treated wastewater. A further survey was carried out by the Ministry of Land, Infrastructure and Transport in FY 2000 showed that removal ratios of these EDs in wastewater treatment process were 70 - 99 % (MLIT, 2001). On the other hand, little was known about the fate of EDs in the sludge treatment process and the fate of EDs accumulated in sewage sludge when the sludge is used for agriculture. Therefore, research and investigation were needed to reveal the fate of EDs and to study countermeasures against EDs in the sewerage system.

METHODS

To make clear the fate of EDs in composted sludge after it is applied to soil, lysimeter method was used. Four lysimeters made of stainless steel were set outside (Photo 1). The schematic diagram of a lysimeter is shown in Figure 1. These lysimeters differed in soil layer conditions such as addition of sewage sludge compost or chemicals (Table 1). Nonylphenol (NP) and 17β-estradiol (E2) were selected as additive chemicals because these

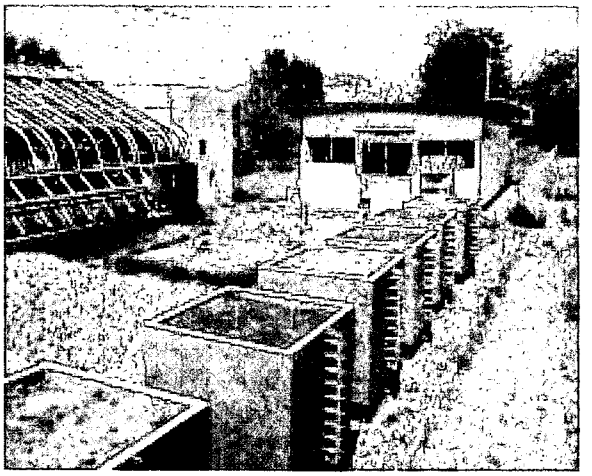


Photo 1 Lysimeters for This Experiment

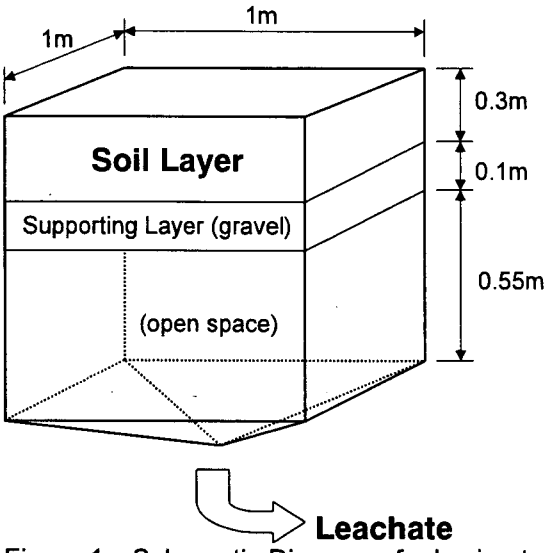


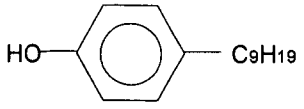
Figure 1 Schematic Diagram of a Lysimeter

Table 1 Experimental Condition of Soil Layer in Each Lysimeter

	Condition of Soil Layer	Legend for Fig.4,5,6
Case 1	Soil (control)	■
Case 2	Soil + Chemicals(NP, E2)	◆
Case 3	Soil + Compost	□
Case 4	Soil + Compost + Chemicals(NP, E2)	◇

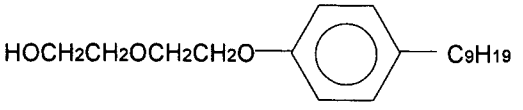
Added chemicals: NP=500mg/lysimeter, E2=17mg/lysimeter

An example of Nonylphenols (NP)



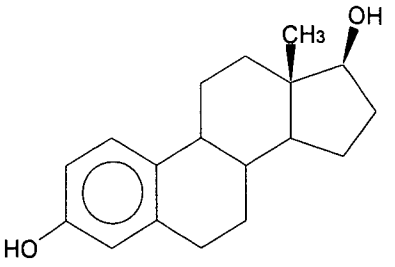
4-nonylphenol

An example of Nonylphenol-poly-ethoxylates (NPnEO)

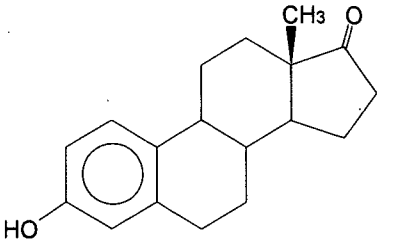


4-nonylphenol-di-ethoxylate

Figure 2 Examples of Nonylphenols



17ß-estradiol (E2)



Estrone (E1)

Figure 3 Examples of Estrogens

trace-compounds were detected in higher amounts at many surveyed points during the national survey.
Figure 2 shows examples of structural formula of NP, which is a chemical that is strongly suspected as EDs. NP is also known as an end product of degradation of nonylphenol polyethoxylates (NPnEO) (Giger *et al.*, 1984) that have been widely used as a detergent. Figure 3 shows structural formula of E2, which is one of human female estrogens.

Samples were taken from leachate and soil for two year and eight months, and NP and E2 were measured. The JSWA analytical methods for wastewater and sewage sludge (JSWA, 2001) were applied, in which NP in soil was extracted with a reflux method and detected with GC/MS, on the other hand, E2 was extracted with an ultrasonic extraction method and detected with enzyme linked immunosorbent assay (ELISA).
According to recent studies, analytical methods used in this experiment have some problems. For example, ELISA must be applied to limited cases, because it reacts with other substances such as estrone (E1) (Komori *et al.*, 2003). When amounts of estrogens in sewage sludge compost were measured using LC/MS/MS, E2 was not detected but E1 was detected from the compost sample. However, because of continuousness of analyzed data, the values obtained using ELISA were treated as amounts of E2.

RESULTS AND DISCUSSION

The total amount of leachate during the experiment was 6.3 - 8.2 times of the soil layer volume.

Figure 4 shows the concentration of total organic carbons (TOC). The concentration of TOC was high until about 100 days. At that time, the total amounts of leachate were approximately 100L.

High concentrations of NP and E2 were detected in the leachate at the early stage of the experiment, and they decreased rapidly along time (Figure 5). These trends were similar to that of TOC in the leachate. The maximum concentration of NP (2.7 µg/L) obtained in this

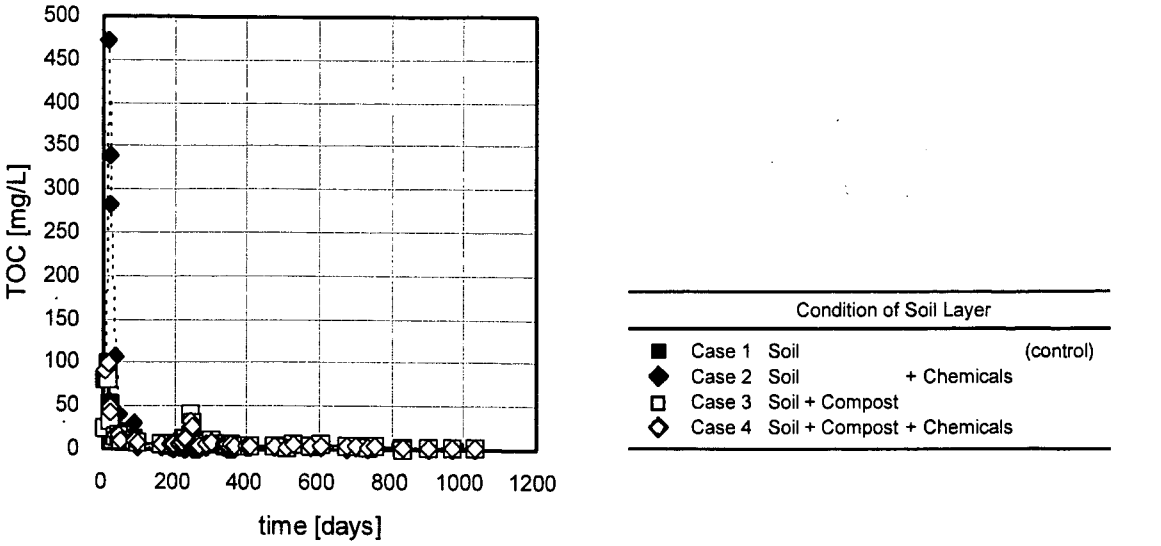


Figure 4 TOC in the Leachate from Lysimeter

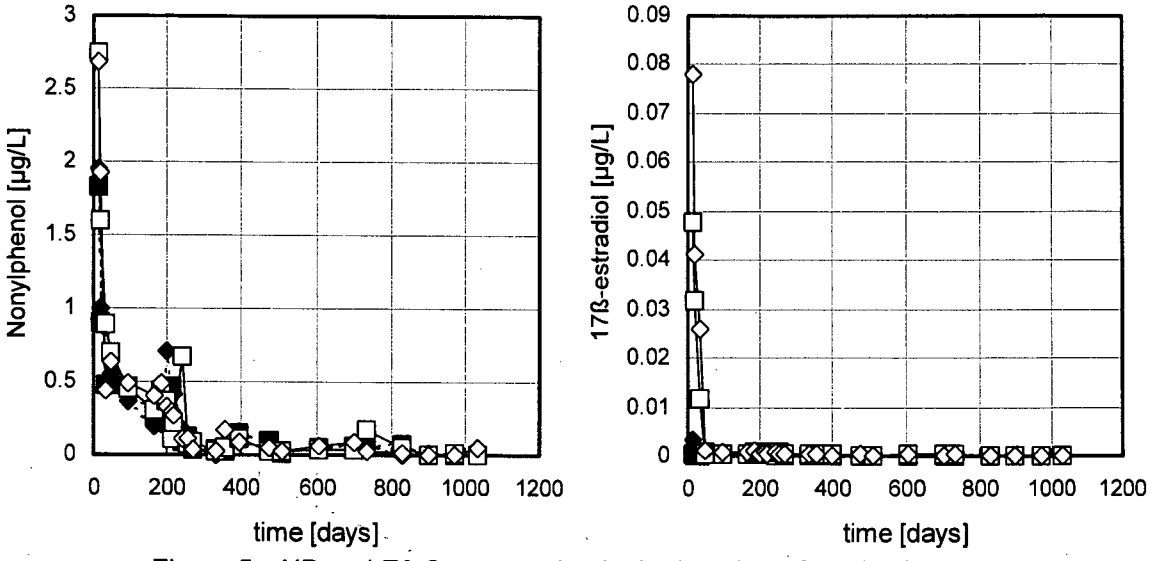


Figure 5 NP and E2 Concentration in the Leachate from Lysimeter

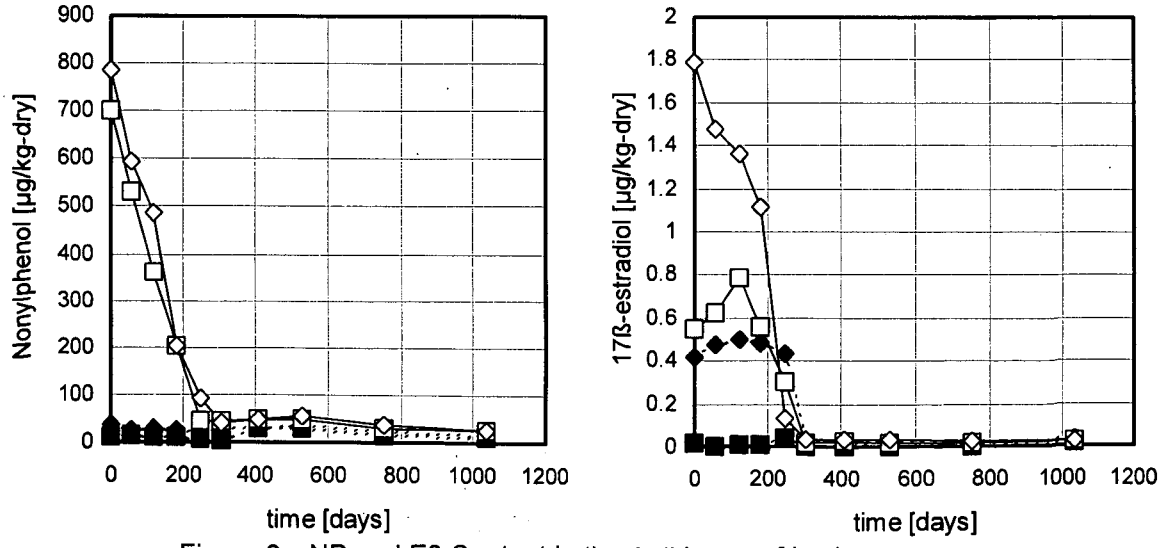


Figure 6 NP and E2 Content in the Soil Layer of Lysimeter

experiment was slightly lower than the proposed water quality criteria of NP for aquatic life (5.9 μg/L for freshwater organisms) that was based on acute and chronic toxicity of NP (U.S.EPA, 2003).
The concentrations of E2 in Cases 3 and 4 with compost was extremely (over 20 times) higher than those in Cases 1 and 2 without compost at the early stage of the experiment. On the other hand, the concentrations of NP in Cases 3 and 4 with compost was only 1.4 - 1.9 times of those in Cases 1 and 2 without compost.
The total amount of NP and E2 which leaked out during the experiment of Cases 3 and 4 were 0.34 - 0.69% and 1.6 - 5.3% of the initial content in the soil layer, respectively. Very small amount of NP and E2 leaked out from the soil layers with showing a lower leakage ratio for NP.

The NP and E2 contents in the soil layer of each lysimeter are shown in Figure 6. High amount of contents were observed in the cases with compost, but they decreased significantly to the almost same level as those of the control after 300 days.

Because the amount of the decrease of NP and E2 in the soil layer was much larger than the amount of NP and E2 that leaked out with rainfall, there must be physicochemical or biological decomposition mechanism in the soil layer.

CONCLUSIONS

To make clear the fate of EDs in composted sludge after it is applied to soil, lysimeter experiment was carried out. By the two year and eight month experiment, it was revealed that very small amount of NP and E2 leaked out from the soil layers and there must be physicochemical or biological decomposition mechanism in the soil layer.

In order to further clarify of the fate of EDs in the sludge treatment process and in the soil with sewage sludge compost, it is necessary to understand the material balance including EDs' relating substances such as NPnEO, nonylphenol carboxylic acids (NPnEC), and E1. However, there is still much to be investigated in relation to analysis of EDs and its relating substances in the sewage sludge samples such as low and unstable extraction efficiency from sludge samples and extremely high amount of other organic substances. Appropriate analysis methods for sewage sludge sample need to be established and further investigation is required to reveal the fate of EDs and to study countermeasures to deal with EDs in the sludge treatment process.

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"OCCURRENCE AND BEHAVIOUR OF TRACE SUBSTANCES IN THE PARTLY CLOSED WATER CYCLES OF BERLIN AND ITS RELEVANCE TO DRINKING WATER"

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ABSTRACT

The daily use of pharmaceutically active compounds and industrial chemicals results in significant effects of trace substances on the environmental media water and soil. Despite effective treatment in the wastewater treatment plants, the load of trace substances on the environmental media is approximately half of the former load in raw sewage. Therefore, trace substances are present in the partly closed water cycles of Berlin.

Berlin has sensitive water bodies with different aspects, e.g. low flow rates, high portions of advanced treated wastewater in the partly closed water cycles and a shallow fresh water aquifer. The water supply system is based on bank filtration and artificial groundwater recharge, and thus a water treatment process close to nature without chemicals can be maintained. Further, no disinfection is necessary.

Several trace substances are removed effectively during bank filtration. Due to higher sludge concentrations and sludge ages, membrane bioreactors show a slightly better performance for the removal of these compounds. Sorption, membrane filtration or oxidation processes can be introduced as a further treatment step at the wastewater treatment plants. For further removal, conventional and new treatment processes have to be applied.

Pharmaceuticals, hormone-disrupting chemicals and cosmetics are not considered to be relevant for drinking water supply due to the low risk level. But there is the need for research activities in terms of the effects of trace substances and the mixture of several compounds on aquatic life or soil organisms.

Measures for minimising the emissions of trace substances in the environment can only be achieved by the implementation of certain targeted minimising strategies in consideration of the application areas. In particular the understanding of the population of the environmental dangers from the use of trace substances is of highest importance. Despite all efforts to protect our environment, a substantial amount of trace substances will also continue to pollute the environment in the future.

Considering the challenge of water management in Berlin, the large research program NASRI "Natural and Artificial Systems of Recharge and Infiltration", which is oriented towards the specific requirements in Berlin, has already been launched. This concerted research action was developed to study in detail all relevant processes in bank filtration and artificial groundwater recharge concerning the hydro-geological conditions and chemical and microbiological quality. The outcome will be a sound basis for optimized operation of existing sites and for the integrated design of new field sites all over the world.

KEYWORDS

Trace substances, partly closed water cycle, drinking water, risk assessment,

TRACE SUBSTANCES AND PATHWAYS INTO THE WATER BODIES

The development of our industrial society has brought about inestimable improvements in human living conditions. But this was accompanied by the development of countless substances and products made for limited-period use, e.g. pharmaceuticals and industrial chemicals. After expiry of the useful life of the products, these substances get into the environment, possibly in modified form. Due to their qualities and their effects, which are partly long term (persistent), the term "problematic substances" was created for them. Since they are occur only in small quantities they are designated trace substances. Regarding the environmental media, water is of highest importance in connection with micro-pollutants because of its function as dissolving agent and means of transport as well as food.
The following emission pathway into the water cycle has to be particularly mentioned:

- Urine and faecal matter in unchanged or metabolised form, improper disposal of substances into toilets and after wastewater collection, leaking sewerage systems, combined sewer overflows, municipal wastewater treatment plants (WWTPs), industrial WWTPs and infiltration plants for rainwater and treated sewage (small WWTPs).
- Recent statistical data on wastewater disposal in Germany shows that 83.4 % of the domestic wastewater are discharged into surface waters via central sewerage systems and WWTPs, while 9.7 % get into the water bodies without being treated, and 6.9 % are infiltrated into soil via decentralized wastewater disposal plants. The share of wastewater infiltrating into the soil through leaking sewers might not be more than 1 % [Dohmann, 2003].

The emissions pathway of pharmaceuticals, which can appear also as hormone disrupting chemicals are shown in Figure 1.

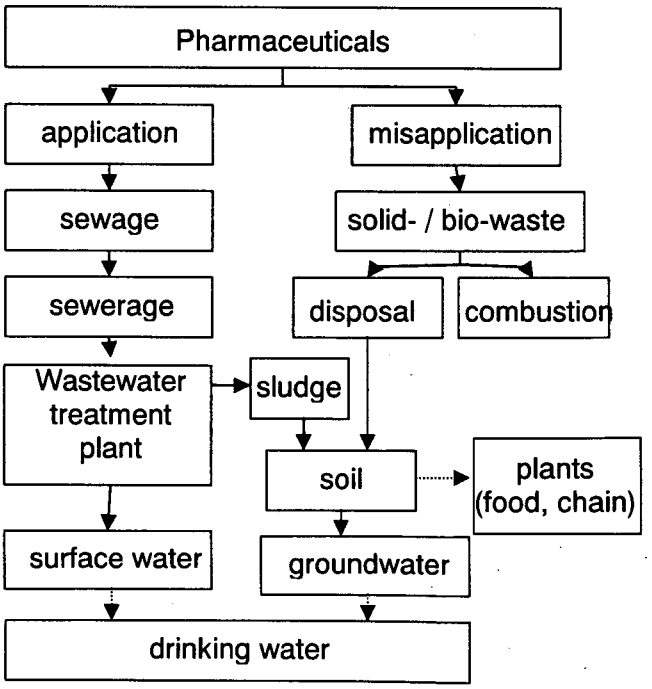

Figure 1 Pathways of pharmaceuticals into the water bodies

BERLIN'S WATER SITUATION AND WATER SUPPLY SYSTEM WITH PARTLY CLOSED WATER CYCLES

Water situation

Approximately 6% of the area of Berlin consists of freshwater (see Figure 2): lakes (e.g. Schlachtensee), river lakes (e.g. Tegeler See, Müggelsee, Wannsee), rivers (e.g. Panke, Wuhle, Erpe), regulated rivers (e.g. Spree, Havel and Dahme) and canals (e.g. Landwehrkanal,

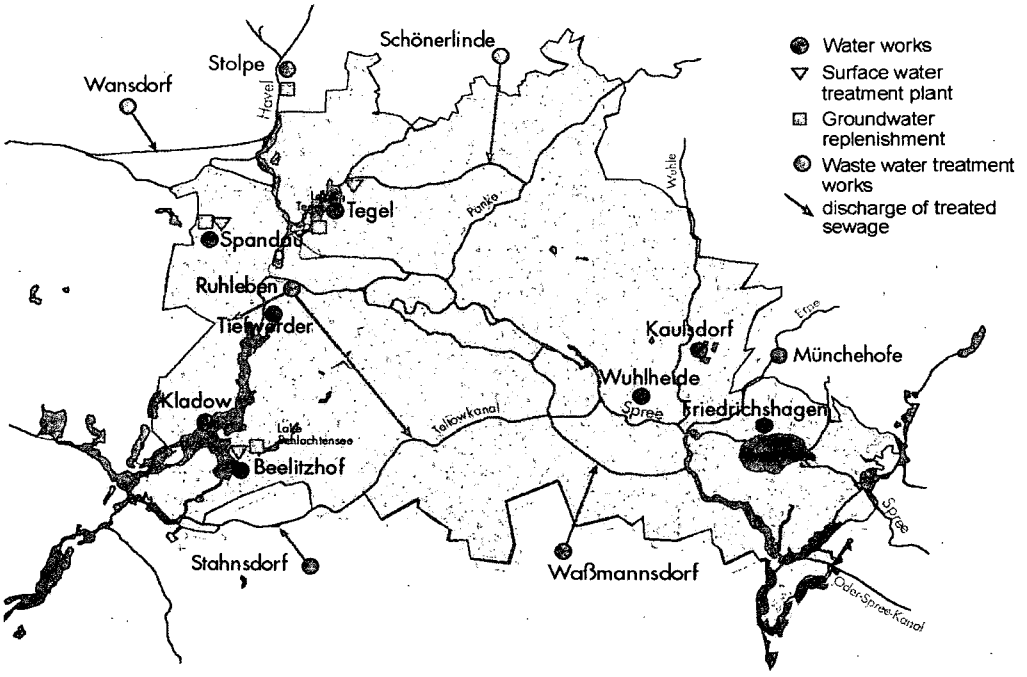

Figure 2 Map of water bodies, water works and treatment plants in the Berlin region

Teltowkanal). The flow rates through Berlin are low (approximately 50 m^3/s) and unsteady and for the river Spree decreasing, because of the closure of open lignite mines from which approximately 1 billion m^3 per year of water was pumped into this river. That means: higher portion of treated wastewater in the receiving waters and longer retention time of the surface water of our regulated rivers and increasing problems with the water quality, particularly in summer when the flow rates of the rivers is very low. The water bodies are therefore very sensitive.

The water bodies are intensively used for different purposes. For the population of the region the water bodies have a high value for recreation but on the other hand they are used economically such as inland fishery and waterways and are important also for water supply. In addition to that, the water bodies are recipients for treated sewage and stormwater from separate system and overflow of the combined sewer system.

Approximately 680 000 m^3 per day of treated municipal wastewater were discharged into the water bodies of the Berlin region in 2002. As a result of the discharge of treated wastewater the water bodies are loaded with nutrients - phosphorus and nitrogen -, ammonia, the bacteriological load, residual organic compounds, particular non-biodegradable compounds and sulphates and chlorides. Investigations have shown that the concentration and the load of

several constituents of urban stormwater from the separate sewer are very high. Zinc, lead, copper, aluminium, iron, organic compounds, phosphorus, filterable solids, suspended substances with adsorbed anthropogenic pollutants - heavy metals and organic micropollutants (e.g. PAH and PCB) - and the bacteriological load, which varies depending upon location, in the storm drainage are an important pollution factor [Heinzmann, 1994]. The quantity of annual stormwater discharge into the water bodies of Berlin is estimated to be at about 60 million m^3 for a mean annual quantity of precipitation of approximately 600 mm.

The quantity of combined sewer overflow at pumping stations is approximately 1 million m^3 per year and of stormwater tanks approximately 3 million m^3 per year. The total quantity of combined sewer overflow is estimated at approximately 7 million m^3 per year. In general, organic substances, ammonia, aluminium, some heavy metals (in decreasing concentrations: zinc, iron, copper, lead, manganese and chromium), and phosphorus and the bacteriological load (in-house investigations) in the overflow of the combined sewer system are an important pollution factor for the water bodies.

Water supply

The glacial sediments found in Berlin and in the surrounding represent excellent aquifers and the vulnerability of the groundwater is obviously high. As a consequence the City of Berlin has been able to sustain its own water supply for several decades based on these following principles:

- The inhabitants of Berlin, just about 3.4 million, are supplied with drinking water by its own groundwater resources exclusively.
- 100% of public water supply in the Berlin metropolitan region comes from groundwater with a contribution of approximately 70% from bank filtration and artificial recharge. The use of bank-filtered water for drinking water supply is very important due to the limited available quantity of natural groundwater. The fresh water aquifer in Berlin is very shallow and beneath an impermeable till layer a huge salty groundwater reservoir follows. At several parts of the city the aquitard between the fresh water aquifer and the salt-water aquifer has holes were salt water is upcoming. The water works has to balance very carefully their pumping regime in order to avoid salt-water intrusion into the fresh water aquifer. No surface water is used in a direct way.
- Regular monitoring investigations for groundwater as well as for surface water are carried out intensively.
- For drinking water treatment only simple techniques (water intake - aeration - manganese and iron removal through filtration) are used. No disinfection is needed. A water treatment process close-to-nature without chemicals can be maintained.

Partly closed water cycles

The Berlin Water works are located nearby the surface water system. Their discharging wells are drilled mostly at a short distance (1 - 600 meter) around the rivers and lakes near the bank to extract bank-filtered surface water. Depending on the location of the water works and the discharge points of for treated sewage and stormwater from separate system and overflow of the combined sewer system, the intensive use of the water bodies for different purposes results in a partly closed water cycle (see Figure 4), which follows a succession of utilisation: water intake - drinking water supply - sewage and stormwater treatment - dilution and self purification in the remaining waters - bank filtration and groundwater replenishment - water intake. Treated wastewater has an influence on the composition of the groundwater and bank-filtered water, particularly in summer, when the flow rate of the Spree River is very low. There is a strong influence of the water works Beelitzhof because a part of the water usually flows from the Teltow canal into the Wannsee (see Figure 2). The drinking water generated at

the water works in Tegel is influenced by treated wastewater of the WWTP Schönerlinde throughout the year (see Figure 2). Highest portion of about 17 - 35 % (mean values, 1993-1998) of advanced treated wastewater are determined in the lake. In addition; one of the largest water works of Berlin (water works Tegel) extracts lake water (80 %) via bank filtration and artificial groundwater recharge. Thus, in Tegel's drinking water it was found that advanced treated wastewater portions were calculated to be 14 – 28 % (mean values, 1993-1998) [Ziegler; 2001]. Because 100 % of the advanced treated wastewater is not recycled at any of these water catchments areas, we do not have a closed water cycle in Berlin. There is no water cycle for the water works Friedrichshagen.

For this reason we have to take sure that these partly closed water cycles are hygienically acceptable and doesn't harm the receiving waters in this densely populated area with approximately 4.3 million people. If we have partly closed water cycles we can not avoid the existence of trace substances at the moment. Berlin's water system with indirect wastewater reuse is limited in its (self-)purification capacity, especially when looking at these persistent, polar organic compounds.

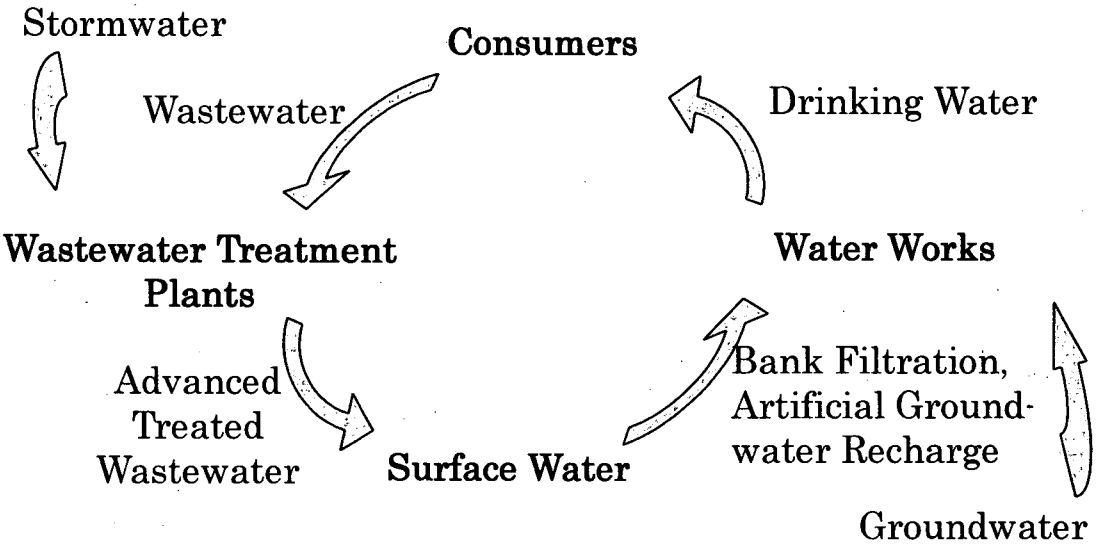

Figure 3 Partly closed water cycle

OCCURRENCE AND BEHAVIOUR OF TRACE SUBSTANCES PARICULARLY PHARMACEUTICALLY ACTIVE COMPOUNDS (PHACS) IN THE AQUATIC SYSTEM OF BERLIN

PhACs in municipal sewage effluents

Several PhACs were observed in repeated investigations of 24h composite samples from different WWTPs in Berlin [Heberer, 2002]. More than 30 PhACs and several similar compounds detected in several investigations of WWTPs in Berlin. Residues of pharmaceuticals from various prescription classes such as blood lipid regulators, analgesics, bacteriostatics, and anticonvulsants were detected up to the µg/L-level in the effluents of the WWTPs in Berlin. However, synthetic estrogens such as 17a-ethinylestradiol and mestranol were only detected at trace-level concentrations in the sewage effluents of the Berlin WWTPs because of their low total amounts in annual prescription. Otherwise, the "phytoestrogen" ß-sitosterol was found at average concentrations of 1.9 µg/L in the effluents from Berlins WWTPs. The estrogenic potential of this compound is, however, very low compared with the above mentioned compounds.

Table 1. Concentrations and removal rates for three drug residues and for caffeine detected in composite samples (24h) of influents (n=10...20) and effluents (n=20...27) from different WWTPs in Berlin* [Heberer, 2002].

Analyte	Average influent concentration in µg/l	Average effluent concentration in µg/l	Removal rate in %
Carbamazepine	1.78	1.63	8
Clofibric acid	0.46	0.48	- **
Diclofenac	3.02	2.51	17
Caffeine	230	0.18	> 99.9

* WWTPs in Berlin: Ruhleben, Schönerlinde, Waßmannsdorf (mixed samples: 24 hours, sampling series in May-December 1999). ** - : no removal was observed.

As exemplarily shown in 1, PhACs such as clofibric acid, the anti-epileptic drug carbamazepine and the analgesic drug diclofenac were not or only to a very small extent removed during sewage purification. On the other hand, caffeine, also originating from PhACs but to a larger extent from beverages and often used as indicator compound for the presence of municipal sewage in the aquatic system, was found to be readily biodegradable and removed by more than 99.9% in Berlins WWTPs. Some PhACs were found in the sewage effluents at concentrations similar or even larger than those of compounds often described as markers for municipal sewage in surface waters, e.g. caffeine or coprostanol (metabolite of cholesterol). The studies of the PhACs showed that some of them are much better suited as marker compounds for municipal sewage than the classical organics because of their persistence in the WWTPs and in the aquatic environment [Heberer et al., 2002].

PhACs in Berlins water ways (results from the surface water monitoring)

Residues of PhACs were identified as important pollutants in a monitoring study carried out in Berlin, Germany, in 1996 [Heberer et al., 1998]. Samples were collected from 30 sampling locations upstream and downstream from the discharged points of advanced treated sewage. The impact and the extend of contamination by the sewage discharges showed the need for further investigations to get more reliable data on the occurrence and behaviour of these residues in the aquatic system. In 1999, further studies on the occurrence of PhACs [Heberer, 2002] were carried out. Additionally, a new long-term monitoring program of sewage, surface, and drinking water for PhACs and several other emerging organic contaminants was initiated in June 2000. In terms of this monitoring program, samples are collected periodically from selected sites in the Berlin area. Some positive findings of PhACs obtained from the first three sampling series in June, September, and December 2000 are compiled in Table 2. Several PhACs have been detected at individual concentrations up to 2 µg/L in Berlins waterways.

More interesting than the total figures are the concentration profiles of the individual compounds measured at the different sampling locations in the Teltowkanal, the Havel river, and the connecting waterways. As expected from the preliminary studies in 1996 and 1999, the highest concentrations for the PhACs were found in the Teltowkanal. Nevertheless, the total loads in the Havel river may be similar or even higher due to the higher flow rates. This question has been clarified by calculating the PhAC loads. But some other interesting aspects can already be drawn from the PhAC concentrations. At the sampling location in the Dahme river PhACs were only detected at very low concentrations or not at all, whereas high concentrations of PhACs were detected in the Teltowkanal caused by discharges of sewage effluents into the canal. Peak concentrations were observed where purified municipal sewage was discharged by the WWTPs. Generally, the impact of sewage effluents on the surface water quality was found to be much more significant for the PhACs than for any of the common chemical parameters [Heberer et al., 1998].

Table 2. Concentrations of PhACs and caffeine detected in terms of the surface water monitoring in Berlin, Germany. Results from the sampling series carried out in June, September, and December 2000. n.d.: not detected.

Compound	Concentrations in ng/l	Compound	Concentrations in ng/l
Amdoph*	n.d. – 830	Mefenamic acid	n.d. – 20
Carbamazepine	25 – 1075	Naproxen	n.d. – 95
Clofibric acid	n.d. – 450	Oxazepam	n.d. – 70
Caffeine	80 – 265	Pentoxifylline	n.d. – 30
Diclofenac	n.d. – 1030	Primidone	n.d. – 635
Gemfibrozil	n.d. – 35	Propiphenazone	n.d. – 1970
Ibuprofen	n.d. – 55	Tolfenamic acid	n.d. – 20
Ketoprofen	n.d. – 65		

* This compound has been identified as a metabolite of a pharmaceutical substance originating from a source at the Upper Havel River outside of Berlin [Reddersen et al., 2002].

The concentration profiles of the PhACs also show some seasonal differences, especially, between the sampling series in June and December 2000. During autumn and winter, the sewage effluents from the WWTP in Ruhleben are discharged into the Spree river which merges with the Upper Havel river. From April to September (bathing season), the Teltowkanal is fed via a pressure pipe-line by additional effluents from the WWTP in Ruhleben. The switching of the force main can be seen very clearly looking at the concentrations of the PhACs [Heberer, 2002]. The concentration profiles of the different PhACs are very similar. Nevertheless, the total amounts of diclofenac detected in December are much higher than those detected in June or September. This is mainly caused by an enhanced photodegradation of diclofenac as also described by Buser et al. (1998).

Behaviour and transport of PhACs during bank filtration

Several PhACs have also been detected up to μg/L-concentrations in wells from different bank filtration sites in Berlin [Heberer, 2002]. In 2001, a new scientific project has been initiated to investigate the natural attenuation of pharmaceutical residues and several other environmentally relevant contaminants systematically under natural conditions at different bank filtration sites in Berlin [Heberer et al., 2001]. This research is carried out in cooperation with the Senate of Berlin (Department of Urban Development, Environmental Protection and Technology) and the Hydrogeology Research Team of the Free University Berlin. Both transects ("Lieper Bucht" and "Wannsee") were built along the Havel River. Some preliminary results obtained for samples collected in April 2001 from the "Wannsee" transect are presented by Heberer et al. (2001). A small compilation of results is also shown in Table 3. Higher concentration found for amdoph in groundwater are due to former infiltration of amdoph from a pharmaceutical plant upstream from the bank filtration site. The average concentration for carbamazepine and primidone are equal or higher in surface water compared to groundwater.

Seven PhACs, namely amdoph (cannot be identified because of potential legal ramifications), bezafibrate, carbamazepine, clofibric acid, diclofenac, primidone, and propyphenazone, were only detected in the shallow wells but not in the deep wells. Several compounds, such as bezafibrate and diclofenac seem to be removed effectively during bank filtration [Heberer et. al, 2001]. But carbamazepine, clofibric acid, primidone, propyphenazone, and amdoph were also present at concentrations of as much as 100 ng/L in the water-supply wells.

Table 3. Concentrations/concentration ranges of some PhACs detected in the surface water of lake Wannsee and in the shallow wells and deep wells from the bank filtration site "transect Wannsee" [Heberer et al., 2001], Berlin, Germany, April, 2001.
[n.d.: not detected; detection level, 1 to 10 nanograms per liter; data are reported in nanograms per liter]

Analyte	Surface water	Shallow wells	Deep wells	Water supply well
Amdoph*	200	135 – 350	n.d.	100
Bezafibrate	170	n.d. - 20	n.d.	n.d.
Carbamazepine	235	160 - 360	n.d.	20
Clofibric acid	50	n.d. – 60	n.d.	70
Diclofenac	50	n.d. – 40	n.d.	n.d.
Primidone	105	195 – 535	n.d.	15
Propyphenazone	280	10 – 170	n.d.	50

* This compound has been identified as a metabolite of a pharmaceutical substance originating from a source at the Upper Havel River outside of Berlin [Reddersen et al., 2002].

OCCURRENCE AND BEHAVIOUR OF IODINATED X-RAY CONTRAST MEDIA IN THE AQUATIC SYSTEM OF BERLIN

Triiodinated benzene derivatives are widely used as X-ray contrast media by intravenous injection. The triiodinated compounds enhance the contrast between organs and the surrounding tissues and enable visualization of organs which otherwise could not be investigated. The compounds are very stable and hydrophilic and are excreted unchanged after some hours of application. The required properties for the application to humans are a disadvantage form the environmental point of view. WWTPs are not able to remove the compounds and thus they are recharged into the receiving surface waters. The concentration of organic iodine compounds, measured as adsorbable organic iodine (AOI), in the effluent of Berlins largest WWTP varies between 50 and 140 µg/L (24 h mixed samples) [Oleksy-Frenzel et al., 2000] and thus, high concentrations of iodinated X-ray contrast media are expected to occur in the receiving waters. Within a partly closed water cycle the AOI decreases, e.g. from 33 µg /L in the initial receiving channel down to 12 µg /L in a receiving lake. A further AOI decrease is recognized during anoxic bank filtration down to 2 to 3 µg/L AOI. Under oxic bank filtration condition the AOI stays nearly constant. Besides monitoring of the sum parameter AOI the concentration of selected iodianed X-ray contrast media were quantified [Putschew et al., 2000, 2001a,b; Putschew and Jekel, 2003; Schittko et al., 2004]. All selected contrast media (Iopromide, Iopamidol, Diatrizoat, Iohexol) are detectable in the influenced partly closed water cycle. The concentration of the compounds in the receiving lake is in the upper ng/L range (e.g. Iopromide 860 ng/L, Diatrizoate 960 ng/L, mean values n=10). During anoxic bank filtration the concentrations are decreased and, in the raw drinking water concentrations in the lower ng/L range are determined (e.g. Iopromide 17 ng/L, Diatrizoate 140 ng/L). Even in the finished drinking water low concentrations of contrast media were detectable.

Comparison of AOI with the single compound concentrations indicates, that the iodinated compounds are transformed during anoxic bank filtration, whereby the transformation products are still iodinated. By LC-ICP-MS analysis, conducted to trace unknown iodinated compounds, some unknown compounds could be detected. Beside the fact, that the ecotoxicological relevance of the transformations product are unknown the emission of the iodinated compounds should be reduced as far as possible e.g. by collection hospital wastewater or separated urine.

REMOVAL OF PHARMACEUTICALS AND PERSONAL CARE PRODUCTS (PPCPS) OUT OF WWTP EFFLUENTS

Wastewaters from houses and hospitals are usually discharged into the sewers and reach the municipal WWTP. Consequently, persistent organic compounds originating from personal care products and pharmaceuticals are being treated in the plant. Depending on their specific properties, they are biodegraded, adsorbed on activated sludge and removed with the excess sludge, stripped out during aeration or leave the plant and appear in the WWTP effluent. Especially extremely polar substances like iodinated X-ray contrast media and neutral compounds like the pharmaceuticals carbamezapine and diclofenac will pass a conventional activated sludge treatment with only minor reduction. If the adjacent water bodies are a further source of water supply, measures have to be taken to remove these compounds out of the WWTP effluent. The situation is as follows:

- The investigated organic compounds usually have a low molecular weight with a maximum of 500 g/M.
- The compounds have a neutral to polar character.
- The compounds appear in a matrix with an organic spectrum of natural organic matter.
- Concentrations of salts can be somewhat elevated.

As a first step, it can be tried to avoid the discharge of these compounds into the water. This can include a separated treatment of hospital effluents as well as a decentralized wastewater treatment with urine separation. However, this is not always feasible and consequently conventional and new treatment processes have to be applied. Due to higher sludge concentrations and sludge ages, membrane bioreactors (MBR) show a slightly better performance for the removal of these compounds. Nevertheless, their application can not avoid the release of these compounds into the aquatic environment. Sorption, membrane filtration or oxidation processes can be introduced as a further treatment step at the WWTP effluent.

Sorption processes:
It is possible to remove organic compounds by sorption on activated carbon or metal oxides. Usually, non-polar substances have a better affinity to the sorption material. Most polar and therefore persistent substances will remain in the water phase. Moreover, high molecular humic substances will cover the sorption places and avoid the transfer of the adsorbent agents into the pores of the activated carbon. Regarding the amount of WWTP effluent to be treated, a treatment by sorption is not feasible in large scale plants.

Membrane filtration:
The aim is to separate polar and small molecular weight compounds. Consequently, a filtration with a low molecular weight cut off like reversed osmosis or nanofiltration processes have to be applied. These techniques will also reject salts and therefore not only fouling (clogging the membrane by organic and inorganic compounds), but also scaling (exceeding the solubility product and precipitation of salts in the concentrate) will occur. The permeate has a low content of salts and quite corrosive. Moreover, even in a multi stage system, 10 % of the influent will reappear in the concentrate stream and has to undergo further treatment. These filtration processes can only be run economically, if the concentrate stream does not need to be treated and if a low salt content is a special requirement e.g. like during groundwater recharge to avoid salt water intrusion into drinking water aquifers.

Oxidation processes
Treatment by sorption and filtration does remove the compounds out of the water phase, whereas an oxidation step aims at a transformation of persistent compounds. The oxidation will be optimised that the oxidation products do not show their former bioactivity any more and are mostly biodegradable. The oxidation processes generally include ozone, ozone/hydrogen peroxide, UV/hydrogen peroxide, and UV/ozone. Out of these, ozone and ozone/hydrogen

peroxide are the most efficient in terms of removal efficiency, energy requirement and cost effectiveness.

At the Technical University Berlin a research project has recently been launched dealing with an ozonation of WWTP effluent with the aim of groundwater recharge. Figure 4 shows the direct oxidation of DOC and the formation of biodegradable DOC with increasing ozone consumption for a WWTP effluent [Schumacher et. al, 2003].

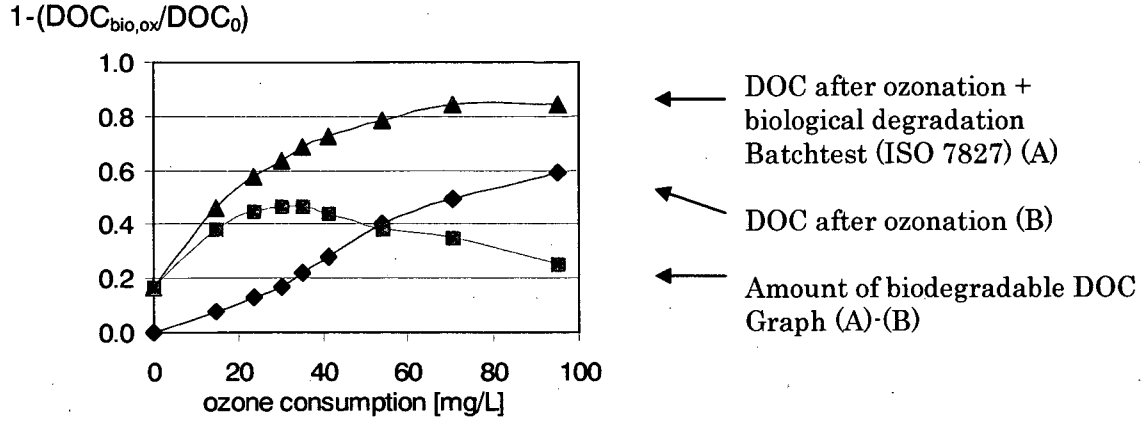

Figure 4: DOC removal during ozonation and enhancement of biodegradability, DOC_0 = 11.5 mg/L.

In this WWTP effluent, 18 % of DOC is biodegraded after a treatment with batch tests for 28 days. By using ozone, DOC can be removed immediately, but very high amounts of ozone have to be applied. For example 60 % of DOC are removed while applying 95 mg ozone/L. A combination of ozonation and biodegradation is much more efficient. Here, the same amount of DOC is reduced by using just 25 mg/L of ozone and a subsequent biodegradation step. A slow sand filtration or a soil passage with a wide range of redox conditions from aerobic to anaerobic will further enhance the removal of organic compounds.

In order to investigate the behaviour of extremely persistent compounds, WWTP effluent was spiked with iopromide, an X-ray contrast compound. It contains an aromatic ring system with three iodine groups, making it polar and poorly degradable. During ozonation, iopromide concentration was quickly decreased. However, the analysis of adsorbable organic iodine (AOI) proved that most of the iopromide was transformed, but only 20 % are removed while applying 25 mg ozone/L.

In a combination of ozonation with 25 mg ozone/L and a subsequent treatment in soil columns with a retention time of 14 days, the results are as follows: DOC, UVA(254), colour and molecular size distribution can be adapted to natural groundwater characteristics. AOI can be decreased by around 35 %, but remains much higher (92 µg/L) than groundwater levels (2.2 µg/L). Anoxic and anaerobic redox conditions will further improve the performance. Moreover, the treatment can be improved by an efficient combination of ozone and hydrogen peroxide. As prices for ozone have decreased tremendously in recent years, overall costs of less than 0.05 Euro per m^3 are realistic.

RELEVANCE OF TRACE SUBSTANCES TO DRINKING WATER QUALITY

The pharmaceuticals, hormone-disrupting chemicals and cosmetics, are not considered to be relevant for drinking water supply due to the low risk level. In order to safeguard against any risk as well as for ecological reasons, water pollution due to persistent synthetic trace substances should, however, be minimised by suitable water protection measures.

Besides the oral taking of drugs, the exposure to endocrine substances basically occurs via ingestion. According to recent findings, water pollution as a result of endocrine substances also at trace-level is to be avoided by means of water protection measures, natural filtration processes and physical-chemical treatment methods, which are to be applied during the drinking-water treatment process .

Owing to their substance properties, cosmetics are to kept out of the drinking water in the course of the natural and physical-chemical treatment processes. For humans, possible exposure to hormone-disruptors via drinking water can be disregarded in comparison to other exposure risks.

According to recent scientific and technical findings, no health risks can be identified as a result of exposure to pharmaceuticals, including veterinarian pharmaceuticals and animal feed additives, as well as to hormone-disrupting chemicals and cosmetics absorbed via the drinking water cycle. On the quantification of the above-mentioned trace substances, their possible furnish and further behaviour in both surface and groundwater should be taken into account. In terms of pharmaceuticals and animal feed additives in particular, the possibility cannot be ruled out that they may get into the wastewater cycle, respectively into liquid manure, subsequently into the surface waters and directly or via bank filtration also into the groundwater.

MINIMISING OF THE EMISSIONS OF TRACE SUBSTANCES IN THE ENVIRONMENT

A decrease in the emissions of pharmaceuticals, hormone-disrupting chemicals and cosmetics can only be achieved by the implementation of certain targeted minimising strategies in consideration of the application areas. The following measures, comprising also additional consumer information, would be suitable:

- Safe disposal of pharmaceutical residues as waste (via pharmacies) and no improper disposal also of cosmetic residues via toilet flush, resp. in case of veterinarian pharmaceuticals via the sewer system,
- Restricted use of cosmetics bearing any health risks and having a high accumulation potential in aquatic animals,
- Critical handling of pharmaceuticals.

The reorganisation of the current application practices and habits should be accompanied by generic suitable measures such as:

- availability of all data relating to consumption quantities and to the ecological impact potential of the marketed substances,
- uniform risk assessment of the environmental behaviour of pharmaceuticals for humans and animals as well as of animal feed additives within the scope of specific admission procedures,
- securing the non-polluting disposal of pharmaceuticals,
- substitution of environmentally relevant cosmetics and industrial chemical by substances having a lower risk potential,
- stopping the use of particularly risky substances which are dispensable for health protection, if necessary restricting or even prohibiting their use as it is already practised with some pesticides and industrial chemicals.

To provide for any risks that would jeopardise future water protection, the main objective of all measures cited above is to safeguard the aquatic ecosystems and existing drinking water resources against avoidable emissions produced by pharmaceuticals, hormone-disrupting chemicals and cosmetics.

CONCLUSIONS

PhACs are found as very persistent residues at the µg/L-level in the effluents of Berlin's municipal WWTPs. These residues are discharged into the surface waters, where they are also detected at concentrations up to the µg/L-level in samples collected from several canals, lakes, and rivers. In particular, several of the polar PhACs were identified as excellent markers for sewage contamination in surface and groundwater because of their persistence in the aquatic environment. Whenever bank filtration or other methods for groundwater recharge are used in drinking water production, these compounds can leach from the contaminated watercourses into the groundwater aquifers and may also appear at trace-level concentrations in drinking water.

The removal of trace substances from raw water has a long tradition (e.g. pesticides) in the drinking water treatment process. In accordance with current knowledge ozonation and sorption by activated carbon can in some cases successfully remove trace substances. The additional pollution in raw water for drinking water supply is lower than in sewage, making a more effective treatment possible. As already mentioned, the water passage through the ground significantly removes several trace substances.

Pharmaceuticals, hormone-disrupting chemicals and cosmetics are not considered to be relevant for drinking water supply due to the low risk level.

OUTLOOK

A sustainable water management in Berlin is based on protection of the quality of surface water as well as groundwater. Berlin has to handle with different aspects e.g. low flow rates, high portions of advanced treated wastewater in the water cycle and a shallow fresh water aquifer. Considering the challenge of water management in Berlin the special R&D project "Natural and Artificial Systems of Recharge and Infiltration" oriented towards the specific requirements in Berlin has been already launched [Fritz et. al, 2003]. The initiated interdisciplinary co-operation project of the Berlin Centre of Competence for Water will continue until May 2005. The project is funded by Veolia Water and the Berlin Water Company (Berliner Wasserbetriebe). The main objective is to develop expertise in the overall management of water resources in terms of bank filtration, artificial groundwater recharge and reuse of sewage and stormwater in a partly closed water cycle [Jekel and Heinzmann, 2003].

In recent years, polar and poorly degradable organic pollutants are gaining increasing attention as a factor of water quality. Industrial chemicals as well as household products, certain pesticides and their polar metabolites and pharmaceutically active compounds are among these polar pollutants. These compounds are not necessarily removed in wastewater treatment and in drinking water preparation processes. Thus, the mechanisms of the removal of impurities and of the chemical reactions of the water components have not been understood sufficiently. As far as some hydrological trends and development of anthropogenic pollutants may threat the future of the groundwater resource in Berlin, it is important to measure the capacity of ground filtration to answer to such developments, and to secure the use of bank filtration and water recharge systems through the development of the most appropriate practices and the related technologies.

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MANAGEMENT OF CHEMICALS IN DRINKING WATER:

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ABSTRACT

The Japanese Drinking Water Quality Standards(DWQSs) were throughly reviewed and revised in 2003. As a result, the number of standard parameters increased from forty-six to fifty. The new DWQSs are to be enforced from 1 April 2004. Chemical constituents newly included in the DWQSs are boron, 1,4-dioxane, bromates, chloroacetic acid, dichloroacetic acid, trichloroacetic acid, formaldehyde, aluminum, geosmin, nonionic surfactant, 2-MIB (methylisoborneol) and TOC. On the other hand, several chemical constituents were excluded from the DWQSs. Regulations related to the DWQSs including the Technical Standards of Water Supply Facilities and the Standards of Structure and Materials of Service Equipment for Water Supply have already been revised or are to be revised in due course. The revision may give a significant impact on the Environmental Water Quality Standards and other water quality standards.

KEYWORDS

Water supply, drinking water quality standards(DWQSs), chemical constituents, health risk assessment, regulation

INTRODUCTION

Water supply is one of the most important social infrastructures supporting our daily life and social activities. We cannot do without continuous supply of safe and good-quality water. In Japan, raw water contamination with chemical constituents aw well as microbial constituents due to industrialization and urbanization is still a serious problem in water supply, and proper water quality management is indispensable for ensuring drinking water safety. On the other hand, deregulation, decentralization and information disclosure towards social structure reformation are key issues in water supply administration. Considering such circumstances surrounding water supply, the current Drinking Water Quality Standards(DWQSs), established in 1992, were thoroughly reviewed and revised in 2003. Regulations related to the DWQSs were also reviewed.

In this paper, the Japanese regulatory framework on chemical constituents in drinking water is introduced and discussed focusing on the revision of the DWQSs. Detailed information on the revision as well as the regulatory framework of water supply administration can be obtained

through the homepages of the Ministry of Health, Labor and Welfare(MHLW)[1] and Water Supply Division of MHLW[2].

CHEMICAL CONSTITUENTS IN DRINKING WATER AND THEIR REGULATORY FRAMEWORK

Basic considerations

Today a variety of synthetic chemicals are produced for our daily consumption and industrial use, and some of them are introduced into water environment. Raw water for drinking water supply is inevitably contaminated with synthetic chemicals depending on human activities in a watershed although measures for preventing raw water contamination are taken. This is the reason why proper water quality management is important in water supply.

Major requirements for ensuring drinking water safety may be summarized as follows:

(1) To select water sources of good quality and to maintain them in good conditions.
(2) To operate water treatment facilities properly along with the changes in raw water quality.
(3) To prevent water quality deterioration in its treatment processes and distribution network.

The first priority for ensuring drinking water safety is to select water sources of good quality. However, there are actually many cases where raw water is contaminated and contaminant removal by water treatment is indispensable. Drinking water contaminants are also derived from its treatment processes and distribution network. The release of lead from lead pipes is one of typical examples. So we should take those matters into account when considering measures for ensuring drinking water safety.

Regulatory framework and present status of drinking water contamination with chemical constituents

In Japan, the Ministry of Health, Labor and Welfare(MHLW) has established the Drinking Water Quality Standards(DWQSs) and the Technical Standards of Water Supply Facilities based on the Waterworks Law. The DWQSs are directly related to drinking water safety with specifying minimum quality requirements of drinking water. Every water utility should regularly examine the parameters listed in the DWQSs and observe the DWQSs. The DWQSs may not be exceeded all the time. The Technical Standards of Water Supply Facilities specify the requirements of water supply facilities from the viewpoints of stable supply of drinking water meeting the DWQSs. The Technical Standards include the standards of materials and chemicals used for water supply for the purpose of preventing drinking water contamination in its treatment and distribution. Moreover, the Standards of Structure and Materials of Service Equipment for Water Supply have been established for the purpose of preventing the release of chemical contaminants from pipes and fittings used in household water supply equipment.

The current DWQSs on chemical constituents were established in 1992 based on latest scientific information at that time so that the consumption of drinking water throughout a lifetime may not give a significant adverse health effect. Drinking water is chemically safe so

long as the DWQSs are observed.

Drinking water quality examination for compliance is regularly being undertaken by water utilities at more than 5,000 stations, mainly at consumer taps, all over Japan. Its result is reported to the MHLW and also disclosed to the public every year. In fact, the DWQSs on chemical constituents have well been observed in Japan. The chemical DWQSs are rarely exceeded, and so far no cases of adverse health effects caused by chemical contamination of drinking water have been reported.

Table 1 shows a basic principle regarding chemical constituents in establishing the three standards, i.e. the DWQSs, the Technical Standards of Water Supply Facilities, and the Standards of Structure and Materials of Service Equipment for Water Supply. The total concentration of a chemical constituent derived from water treatment chemicals, materials used for water supply, and materials used for service equipment may not exceed 30% of its standard value, which means the concentration of a chemical constituent derived from raw water may not exceed 70% of its standard value.

Table 1 Basic principle on chemical constituents in establishing the three standards

Derivation	Allowable level
Raw water	<70% of DWQSs
Water treatment chemicals	<10% of DWQSs
Materials used for water supply	<10% of DWQSs
Materials used for service equipment	<10% of DWQSs

We have no raw water quality standards for drinking water supply in Japan. Instead, the Environmental Water Quality Standards(EWQSs) have been established. One of the purposes of establishing the EWQSs is to conserve drinking water sources. Furthermore, there are the Law of Execution of Preservation Project of Water Resource for Water Supply(Project Execution Law) and the Law Concerning Special Measures to Preserve Water Quality of Water Resource for Drinking Water(Special Measures Law) for the purpose of raw water protection.

REVIEW AND REVISION OF THE DWQSs ON CHEMICAL CONSTITUENTS

Background and consequence of review

The current DWQSs were established more than ten year ago. Since then, the circumstances surrounding water supply have changed very much. For example, the contamination of drinking water with dioxins and endocrine disrupting chemicals is a matter of great concern. Contamination with chlorine-resistant pathogens, like *Cryptosporidium*, is also a serious problem for water utilities. On the other hand, new scientific information on drinking water contaminants has well been accumulated. In addition, the latest edition(i.e. second edition) of the WHO Guidelines for Drinking-water Quality, which were referred to when establishing the current DWQSs, are going to be revised. Those are the main reasons of reviewing the current

DWQSs.

The MHLW organized a Drinking Water Quality Management Committee under the Health Science Council for the purpose of reviewing the current DWQSs in 2002, and the council submitted its report[3] on the result of review in April 2003. The new DWQSs accordingly revised were promulgated on 30 May 2003, and they are to be enforced from 1 April 2004. New regulations related to the DWQSs have already been revised or are to be revised in due course.

Basic principles of reviewing DWQSs

The basic principles of reviewing the current DWQSs are as follows:

(1) All the parameters, which do not often occur in drinking water but may have a potential of adverse health effects or cause troubles in its daily use other than drinking purpose depending on location, type of water source and water treatment system, should be included in the DWQSs.

(2) All water utilities should implement drinking water quality examination for compliance on essential parameters at a specified frequency, but they may be allowed to minimize the frequency of examination for compliance on the other parameters depending on their own situations.

In total, approximately 200 chemical constituents have been reviewed, and standard parameters were selected according to the principles as described above. A reference value had been established for each chemical constituent prior to selecting a standard parameter and establishing a standard value. The criteria of selecting a standard parameter are that a chemical constituent has a potential of adverse health effects or cause troubles in its daily use other than drinking purpose, and that it has occurred in drinking water at concentrations exceeding 10% of its reference value. Chemical constituents, that do not satisfy both criteria, have not been selected as standard parameters even if they may have a potential of adverse health effects.

A reference value of a chemical constituent with a potential of adverse health effects was derived based on its health risk assessment. Basic considerations in health risk assessment remained unchanged as before. Chemical constituents with potential health risks were classified into two groups according their carcinogenicity and genotoxicity. A health-based reference value of each group of chemical constituents was calculated as described below. Dose-response relationships of carcinogens and non-carcinogens can be assumed as shown in Figure 1.

(1) Non-carcinogens(including carcinogens without genotoxicity)

Reference value = TDI × body weight(50kg) × AF / water consumption(2 liters/day)

where TDI = NOAEL / UF

TDI: Tolerable daily intake in mg/kg/day

NOAEL: Non-observable adverse effect level in mg/kg/day

UF: Uncertainty factor(100 or more)

AF: Allocation factor for water(10% or 20% for most chemicals)

(2) Carcinogens(excluding carcinogens without genotoxicity)

Reference values were calculated setting a health risk level at 10^{-5} in principle.

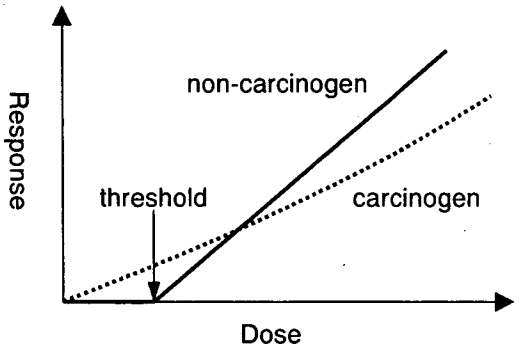

Figure 1 Dose-response relationship

If necessary, a reference value of a chemical constituent obtained as described above was slightly modified taking its analytical achievability and treatability into account when establishing its standard value.

A reference value of a chemical constituent, which cause troubles in daily use of water other than drinking purpose, was established considering a level at which difficulties may arise. Analytical achievability and treatability were also taken into account when establishing its standard value.

Revision of the DWQSs

As a result of the revision, the number of standard parameters increased from forty-six to fifty as shown in Table 2. Chemical constituents newly included in the DWQSs are boron, 1,4-dioxane, bromates, chloroacetic acid, dichloroacetic acid, trichloroacetic acid, formaldehyde, aluminum, geosmin, nonionic surfactant, 2-methylisoborneol(2-MIB) and TOC. On the other hand, several chemical constituents were excluded from the DWQSs.

Table 2 Revision of the DWQSs and guidelines related to drinking water quality

Category			Status of specified value	Number of parameters	
Revised standards/ guidelines	Standards	Relating to human health	Standard value	30	50
		Relating to basic water quality		20	
	Guidelines on Parameter relating to Drinking Water Quality Control		Target value	27	
Current standards/ guidelines	Standards	Relating to human health	Standard value	29	46
		Relating to basic water quality		17	
	Guidelines on Parameters relating to Acceptability		Target value	13	
	Guidelines on Monitoring Parameters		Guideline value	35	
	Guidelines on Pesticides used in Golf Courses		Target value	26	

In addition to the DWQSs, the Parameters relating to Water Quality Control, together with their target values, were newly established, instead of the Parameters relating to the Acceptability, the Monitoring Parameters and the Pesticides Used in Golf Courses. They include twenty-seven chemical constituents that are not so important as standard parameters

but occur or likely to occur in water environment and attention should be paid to in drinking water quality control.

Table 3 shows the revised DWQSs. Scientific information used for the revision of the DWQSs are summarized in a document[4], and authorized analytical methods on standard parameters are described in a notice of the MHLW. The Technical Standards of Water Supply Facilities and the Standards of Structure and Materials of Service Equipment for Water Supply will be revised according to the revision of the DWQSs in due course, and their revised standards are to be enforced from 1 April 2004. It has also been decided that a new system of rolling revision of the DWQSs will be introduced as the WHO Guidelines for Drinking-water Quality.

Table 3 New Japanese Drinking Water Quality Standards(To be enforced from 1 April 2004)

No	Parameter	Standard value	No	Parameter	Standard value
1	Standard plate count	< 100 /ml	26	Total trihalomethanes	< 0.1 mg/l
2	*E. coli*	Not detected	27	Trichloroacetic acid	< 0.2 mg/l
3	Cadmium	< 0.01 mg/l	28	Bromodichloromethane	< 0.03 mg/l
4	Mercury	< 0.0005 mg/l	29	Bromoform	< 0.09 mg/l
5	Selenium	< 0.01 mg/l	30	Formaldehyde	< 0.08 mg/l
6	Lead	< 0.01 mg/l	31	Zinc	< 1.0 mg/l
7	Arsenic	< 0.01 mg/l	32	Aluminum	< 0.2 mg/l
8	Chromium(VI)	< 0.05 mg/l	33	Iron	< 0.3 mg/l
9	Cyanides and cyanogen chloride	< 0.01 mg/l	34	Copper	< 1.0 mg/l
			35	Sodium	< 200 mg/l
10	Nitrate- and nitrite-nitrogen	< 10 mg/l	36	Manganese	< 0.05 mg/l
			37	Chlorides	< 200 mg/l
11	Fluorides	< 0.8 mg/l	38	Hardness	< 300 mg/l
12	Boron	< 1.0 mg/l	39	Total suspended solids	< 500 mg/l
13	Carbon tetrachloride	< 0.002 mg/l	40	Anionic surfactant	< 0.2 mg/l
14	1,4-Dioxane	< 0.05 mg/l	41	Geosmin	< 0.00001 mg/l[1)]
15	1,1-Dichloroethylene	< 0.02 mg/l	42	2-Methylisoborneol	< 0.00001 mg/l[1)]
16	*cis*-1,2-Dichloroethylene	< 0.04 mg/l	43	Nonionic surfactnt	< 0.02 mg/l
17	Dichloromethane	< 0.02 mg/l	44	Phenols	< 0.005 mg/l
18	Tetrachloroethylene	< 0.01 mg/l	45	Organic matter(Total organic carbon)[2)]	< 5 mg/l[2)]
19	Trichloroethylene	< 0.03 mg/l			
20	Benzene	< 0.01 mg/l	46	pH	5.8 - 8.6
21	Chloroacetic acid	< 0.02 mg/l	47	Taste	Not abnormal
22	Chloroform	< 0.06 mg/l	48	Odor	Not abnormal
23	Dichloroacetic acid	< 0.04 mg/l	49	Color	< 5 units
24	Dibromochloromethane	< 0.1 mg/l	50	Turbidity	< 2 units
25	Bromates	< 0.01 mg/l			

Note 1) Both standard values on Parameter 41 and 42 shall be 0.00002 ng/l, instead of 0.00001ng/l, until the day of 31 March 2007.

2) The standard value on total organic carbon(TOC)(Parameter 45) of 5 mg/l shall be replaced with that on permanganate consumption of 10 mg/l until the day of 31 March 2005.

Bromates have newly been included in the DWQSs. Their cancer risk is 2B according to the classification by the International Agency for Research on Cancer(IARC). The causes of their existence in drinking water are raw water contamination, formation in ozonation as by-products and contamination of a sodium hypochlorite solution. Bromates formation potential in ozonation is higher at higher raw water bromides concentration. Bromates in a

sodium hypochlorite solution are derived from impurities(i.e. bromides) in sodium chloride as its raw material.

1,4-Dioxane has also newly been included in the DQWSs. Its cancer risk is 2B which is the same as bromates. 1,4-Dioxane has widely been used as a stabilizer for organic solvents, e.g. 1,1,1-trichloroethane. It has been found that 1,4-dioxane sometimes occur in groundwater at very high concentrations.

Total organic carbon(TOC) is a good water quality index of total organic substances in water. Although we continued to use permanganate consumption for such a purpose for many years, it is evident that TOC is far better than that. The standard value of 5mg/l on TOC may be reviewed after several years. If necessary, permanganate consumption can still be used, instead of TOC, until 31 March 2005. Its standard value is 10mg/l in that case.

Aluminum was newly selected as a standard parameter from the aspect of discoloration but not from the aspect of its potential health effects. Whether its standard value should be 0.1 or 0.2mg/l was a point of discussions. Its standard value may be strengthened from 0.2 to 0.1mg/l in near future.

Both 2-MIB and geosmin are the causes of musty odor of drinking water. Both of their standard values are 0.1ng/l but provisionally 20ng/l until 31 March 2007. Many water utilities, having a problem of musty odor due to eutrophication of source water, will be compelled to adopt activated carbon treatment.

The standard value of lead was already strengthened from 0.5mg/l to 0.1mg/l in March 2002, and the new standard was enforced from 1 April 2003. Lead contamination of drinking water is due to its release mainly from lead service pipes. The replacement of lead pipes is being undertaken, but it may still take many years.

Table 4 shows the Parameters relating to Drinking Water Quality Control as well as their target values. Pesticide contamination of drinking water is of great concern. Although no pesticides were selected as standard parameters, they were included in the Parameters relating to Drinking Water Quality Control, where it is required that the sum of a ratio of a detected value to a target value on each of 101 specified pesticides will not exceed 1.

Regulations related to the DWQSs

According to the revision of the DWQSs, existing regulations related to the DWQSs have been revised and some regulations have newly been introduced. Important ones are as follows:

(1) Sampling points and frequency of regular water quality examination

Water utilities are required to examine drinking water quality on standard parameters at consumer taps, but they are allowed to examine drinking water quality at the outlet of a water treatment plant on some parameters whose concentration will not increase in a distribution

network. The new regulation requires a water utility to select one or more sampling point(s) in each distribution area.

Table 4 Parameters relating to Drinking Water Quality Control

No	Parameter	Target value	No	Parameter	Target value
1	Antimony	< 0.015 mg/l	17	Hardness(Ca, Mg)	10-100 mg/l
2	Uranium	< 0.002 mg/l(p)	18	Manganese	< 0.01 mg/l
3	Nickel	< 0.01 mg/l(p)	19	Free carbon dioxide	< 20 mg/l
4	Nitrite-nitrogen	< 0.05 mg/l(p)	20	1,1,1-Trichloroethane	< 0.3 mg/l
5	1,2-Dichloroethane	< 0.004 mg/l	21	Methyl-*t*-butyl ether (MTBE)	< 0.02 mg/l
6	*Trans*-1,2-Dichloroethylene	< 0.04 mg/l			
7	1,1,2-Trichloroethane	< 0.006 mg/l	22	Organic matter (Permanganate consumption)	<3 mg/l
8	Toluene	< 0.2 mg/l			
9	Di(2-ethylhexyl)phthalate	< 0.1 mg/l			
10	Chlorites	< 0.6 mg/l	23	Threshold odor number	< 3 TON
11	Chlorates	< 0.6 mg/l	24	Total suspended solids	30-200 mg/l
12	Chlorine dioxide	< 0.6 mg/l	25	Turbidity	< 1unit
13	Dichloroacetonitryl	< 0.04 mg/l(p)	26	pH	Around 7.5
14	Chloral hydrate	< 0.03 mg/l(p)	27	Corrosiveness(Langelier's index)	> -1
15	Pesticides	< 1*)			
16	Residual chlorine	< 1 mg/l			

*) As the sum of a ratio of a detected value to a target value on each of 101 specified pesticides.

The requirement of examination frequency was reduced from once a month to four times a year in principle. The new regulation also allows a water utility to reduce examination frequency on some specified standard parameters that are not important to it, e.g. carbon tetrachloride in the case of taking surface water.

(2) Quality assurance/control(QA/QC) of water quality examination

Water utilities are allowed to entrust their duty of compliance examination to a third party, including private laboratories. Since the drinking water quality examination is a very important task for ensuring its safety, laboratories engaged in the examination should well be qualified. Laboratories other than those of water utilities are required to get an approval of the Minister of Heal, Labor and Welfare at present, but they will be required only to be registered in the new regulation. Laboratory qualifications for registration will be established in due course.

(3) Water Quality Examination Plan

Each water utility are required to develop a Water Quality Examination Plan including such information as written below according to the new regulation. Water utilities are also required to disclose the plan to their consumers.

1) Water quality profile from a source to consumer taps, causes of drinking water contamination, and priority parameters in water quality control
2) Parameters regularly examined, sampling points and examination frequency together with the basis of frequency setting
3) Parameters not regularly examined together with the basis of their selection

4) Extra examination of drinking water quality
5) Whether drinking water quality will be examined by their own or by a third party
6) Others(evaluation of examination result, review of the plan, QA/QC of water quality examination, and information exchange with stakeholders)

Subjects to be further reviewed

The report[3] of the Health Science Council suggests that remaining subjects to be further discussed are as follows:

(1) DWQSs on aluminum, unpleasant microorganisms and viruses(to be reviewed in the rolling revision processes)
(2) Measures against *Cryptosporidium*
(3) Drinking water quality management practices
(4) The necessity of including the parameters relating to basic drinking water quality in the DWQSs

CONCLUSIONS

The new DWQSs and related regulations are to be enforced from 1 April 2004. They will give an impact to drinking water quality management practices in water utilities. The most important point in the revision of drinking water quality regulations including the DWQSs is that a water utility will partly be allowed to select standard parameters to be regularly examined on its own responsibility. Such flexibility will favor water utilities. Furthermore, a Water Quality Examination Plan will surely become a good tool for a water utility to communicate with consumers and other stakeholders.

The DWQSs are the key water quality standards that are closely related to other water quality standards, e.g. the Environmental Water Quality Standards. The inclusion of new standard parameters such as TOC, 1,4-dioxane, nonionic surfactant, 2-MIB and geosmin as well as *E. coli* may give a significant impact on those other standards.

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STATE-OF-THE-ART IN DRINKING WATER TREATMENT IN GERMANY

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ABSTRACT

Due to increasing raw water pollution in the fifties, sixties and seventies, drinking water technology became very developed and a lot of new processes were installed. The main raw water source in Germany is groundwater, however also rivers, riverbank filtrate, reservoirs, lakes and other surface water sources are used. In the history of drinking water treatment, slow sandfiltration, chlorination, flocculation and filtration were the first processes. Today, modern oxidation processes like ozonation and advanced oxidation (AOP), adsorption technologies like activated carbon, new disinfection means, like chlorine dioxide and UV are state-of-the-art. Membranes are used more and more, specially for particle removal, the control of microorganisms and the reuse of backwash waters. A lot of research is done to optimize existing processes and to optimize them for the needs of today and the future. Cost is playing an important role, so cost effective technologies and optimization processes are developed. The general philosophy for the production of a safe and healthy drinking water is the use of a multiple barrier system. This multiple barrier safety system starts already with the protection of the raw water source. A good raw water quality ensures already a good product quality. Not just one specific technology, but the combination of different treatment steps are used. The range of possible hazards is wide, so a system of different acting processes may cover the problems, which may even include unknown risks. The multiple barrier approach guarantees a high quality and safe drinking water to our people.

KEYWORDS

Drinking water treatment, bank filtration, particle removal, disinfection, distribution system

INTRODUCTION

About two thirds of Germanys drinking water is produced from protected deep groundwater. Other raw water sources for waterworks are bankfiltrate (16 %), dam-water (9 %) and spring water (8%). The direct use of river water and other sources is limited to approximately 3 % of the total drinking water production (Fig. 1). The annual production of the German waterworks reach nearly 5 billion m^3. The mean drinking water consumption is 128 L/consumer/day. Drinking water sales are going back since ten years, due to measures in the industry (recycling etc.) and due to the savings in private households.

The quality of drinking water is regulated by the drinking water guideline of the European Union (1998), which was transferred in to national right by the German Drinking Water Guideline (2003). The German guideline includes a list of registered additives, which are allowed for use in drinking water treatment. Technical rules for water treatment are issued by the DVGW, the German Gas and Waterworks Association. The technical equipment may follow the rules of the DIN, the German Institute for Standardization. The Federal Environment Agency (UBA)

recommends quality targets for raw, treated and finished water.

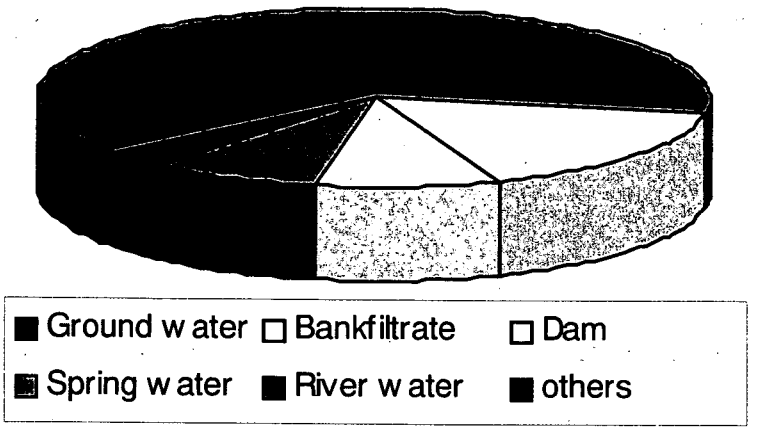

Figure 1: Sources for drinking water production in Germany (BGW, 2002)

Focussing the treatment technology, higher quality standards lead to a more and more sophisticated and sometimes expensive treatment. Nevertheless, the market forces the water works to look for economic solutions. Therefore, the treatment technology in a waterworks should be focussed on site specific problems, the raw water quality and the possible risk potential of the raw water source.

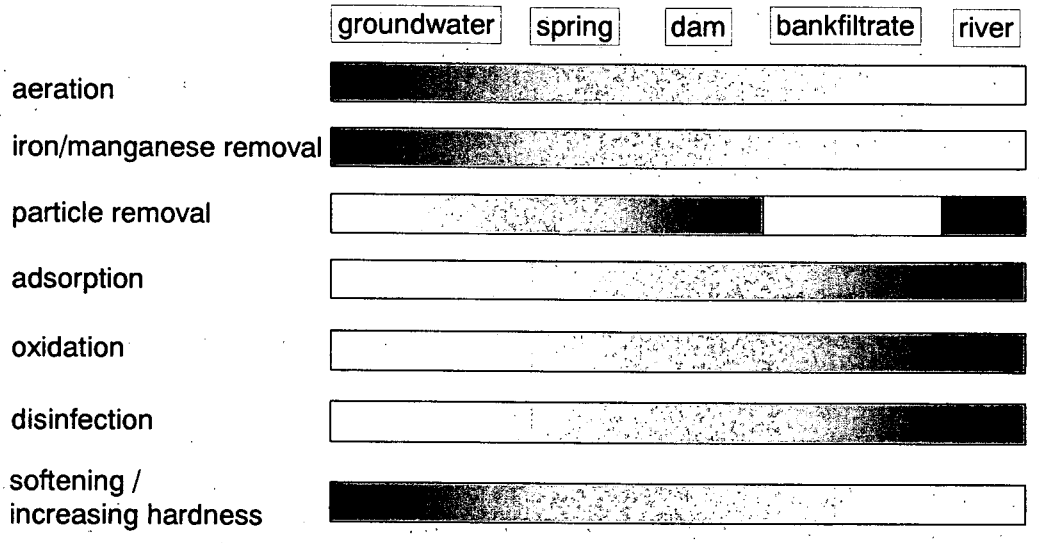

Figure 2: Origin of raw water and applied treatment technology

As Fig. 2 shows groundwaterworks use mostly aeration, rapid filters to remove iron and manganese and sometimes technologies for water softening. Only in cases of special hazards (e.g. farming (pestizides, nitrates), pollution) additional treatment is used. In general, a removal step for micropollutants or a disinfection is not required for groundwaterworks due to a careful protection of the catchment area. Water treatment, which means in Germany a multiple barrier system, starts with the protection of the raw water source. Waterworks using surface water focus their treatment on removal of particles, micropollutants and microbiological risks.

BANKFILTRATION – A PROCESS CLOSE TO NATURE

Waterworks using river water favor the bankfiltration or infiltration as the first treatment step (Fig. 3). Bank filtrate is river water, passed through the river banks. The infiltration is often characterized by pretreatment of the river water, e.g. by flocculation, followed by trickling in certain basins in the underground to enrich the groundwater. Bank filtrate and infiltrate are collected from the underground by wells, followed by a further treatment in a waterworks. Infiltration is often applied, if the quantity of water provided by bank filtration is too low, or bank filtration is impossible due to the geological conditions. Both processes show, that the German treatment philosophy likes to include a very natural step, like an underground passage (Kuehn and Mueller, 2000).

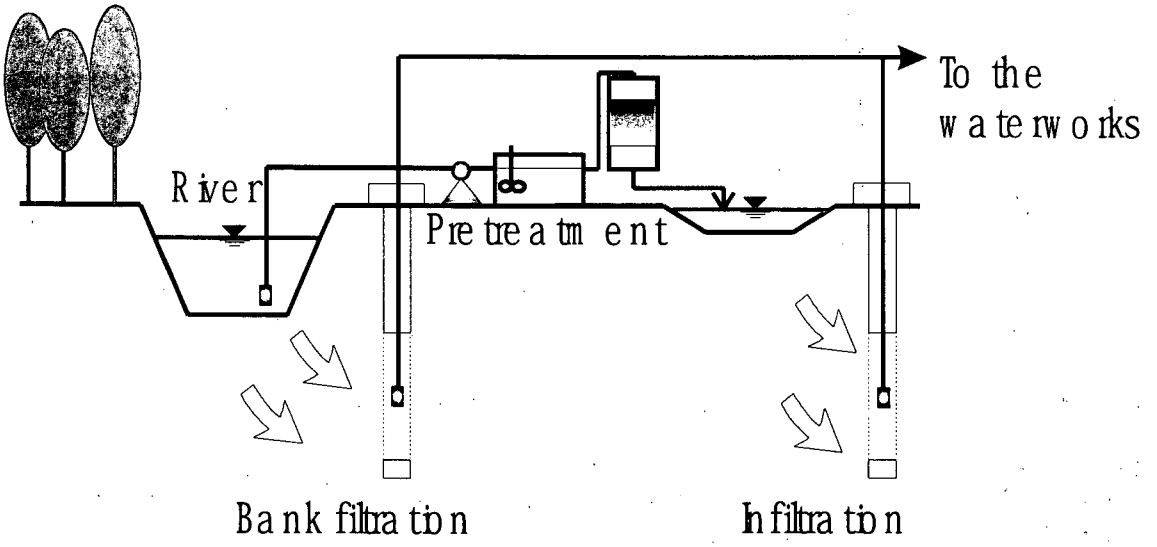

Figure 3: Principle of bankfiltration and infiltration

In recent years the importance of the underground passage grew worldwide, nevertheless the bank filtration has a long tradition in Germany. This is due to several advantages of the underground passage. First of all the underground passage is a natural process. The underground passage removes particles, bacteria, viruses, parasites and the whole spectrum of biodegradable compounds. It is well known, that a river water is characterized by extreme varying concentrations, depending on the water flow, seasonal effects, emissions by municipal and industrial sewage, runoff etc. However, these concentration peaks are compensated and blended during an underground passage.

Important reasons for this concentration compensation are the different retention time, required for a water particle to flow from the river bottom through the underground to a well or the different porosity of the soil. Therefore, the underground passage acts as a barrier against shock loads, caused e.g. from emergency situations such as defects in industrial wastewater plants as shown in Figure 4. The compensation of temperature peaks will improve the water quality, too. The bank filtration has no effect on recalcitrant substances. Therefore the treatment of bankfiltrate often includes granular activated carbon filters.

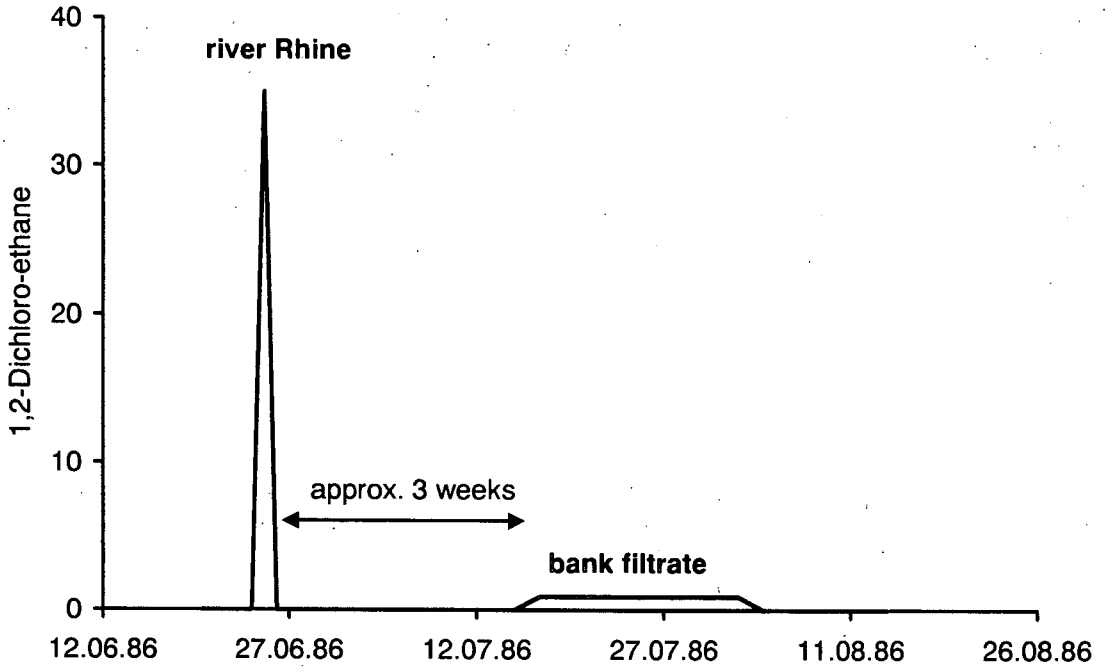

Figure 4: Protection against shock loads during bank filtration (Sontheimer, 1991)

Some examples demonstrate the effect of bankfiltration of the river Rhine in Germany. Figure 5 compares DOC-concentrations in the river water and in the bank filtrate for a waterworks in the central Rhine area in recent 25 years.

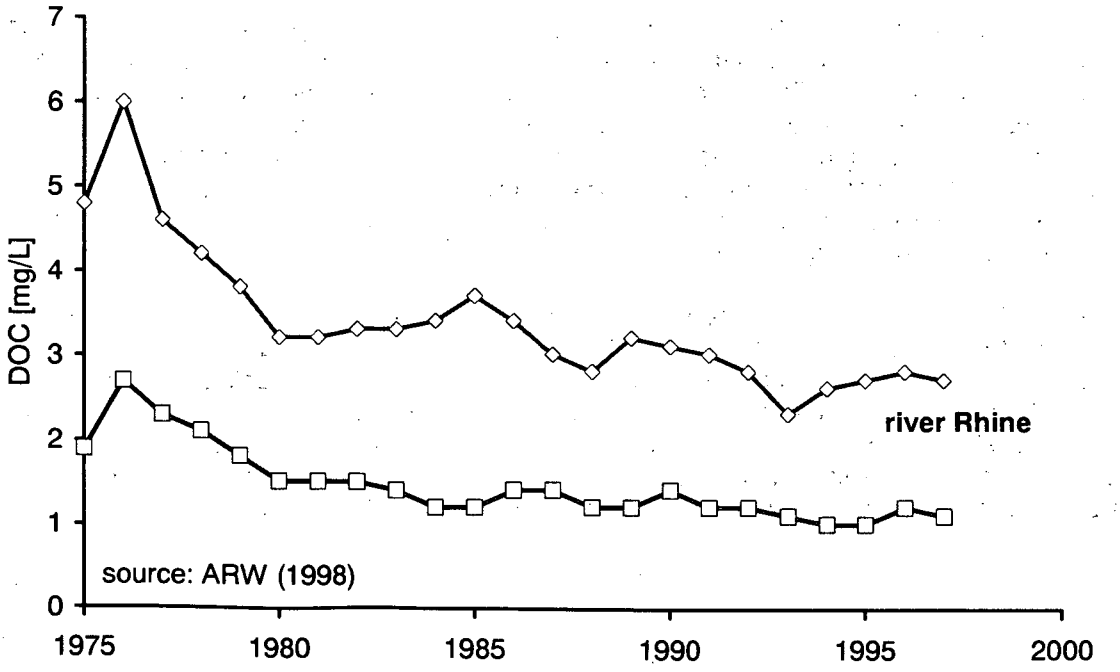

Figure 5: Long term behavior of organic carbon removal while bankfiltration at the Rhine river (Denecke et al., 1998)

Between 1975 and 1997 the DOC-concentration in the river dropped from approximately 5 mg/L to 3 mg/L. A similar decrease of the DOC-concentration was found in the bankfiltrate. The results indicate, that the underground passage has a nearly constant efficiency to remove biodegradable substances dissolved in the river water. Regarding biodegradable compounds, 70 to 100 percent of the removal is done in the underground passage. A reliable and also cheap process.

Even for some micropollutants the underground passage acts as a barrier. An example is given with Fig. 6, demonstrating concentrations of various pharmaceutical compounds in the Rhine river, the bank filtrate and in the drinking water. Some pharmaceuticals such as sotalol or diclofenac were completely removed by bank filtration. Some other pharmaceuticals, e.g. carbamacepine or amidotrizoic acid, pass the underground. Therefore it is necessary to remove these recalcitrant substances in further treatment steps in the waterworks by ozone and activated carbon, whatever process is necessary for the given compound.

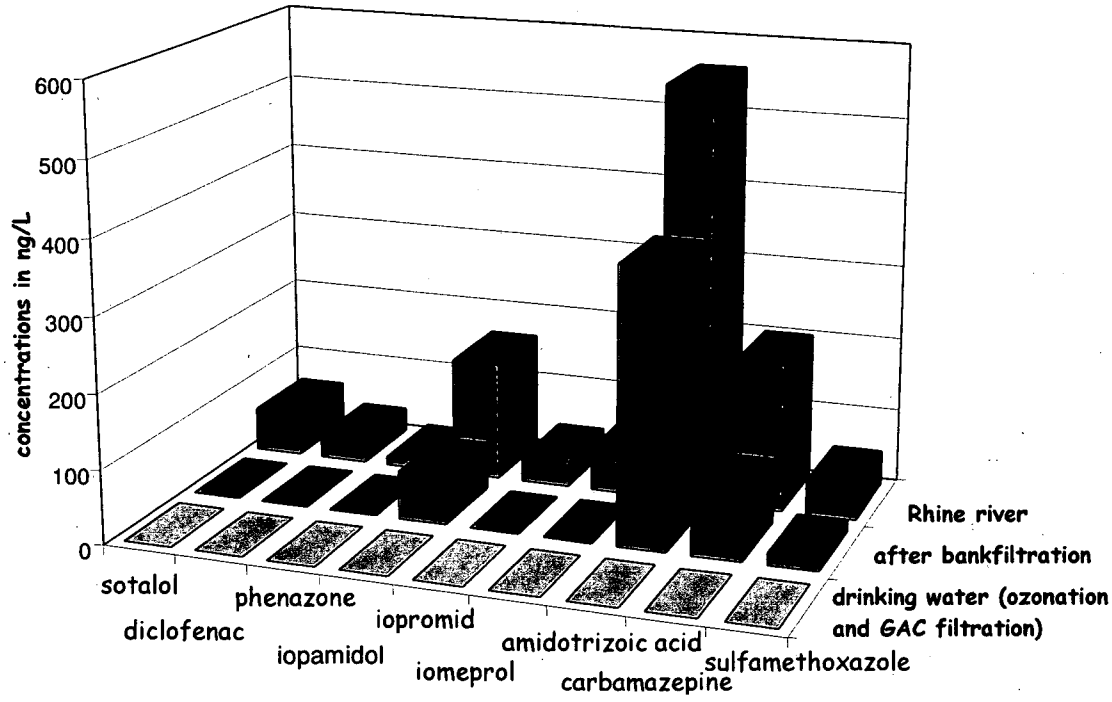

Figure 6: Influence of bank filtration and treatment in the waterworks on removal of pharmaceuticals (Sacher, 2002)

PARTICLE REMOVAL

A sampling campaign was conducted to quantify the occurrence of parasites in surface waters and in waters under influence of surface water. 13 reservoirs and 19 springs were evaluated. Nevertheless, the campaign is not representative for the general raw water situation in Germany, it allows an first indication about the requirements on the waterworks for particle removal. As Fig. 7 shows, in 26 % of the samples collected in dams no Cryptosporidium were detected. In about 60 % of the samples less than 1 Cryptosporidium in 100 L were found. Approximately 70 % of the samples from spring waters showed negative findings for parasites. This campaign indicated, that the parasite concentration in raw waters used for drinking water treatment is relatively low, showing the success of protection measures in the catchment areas.

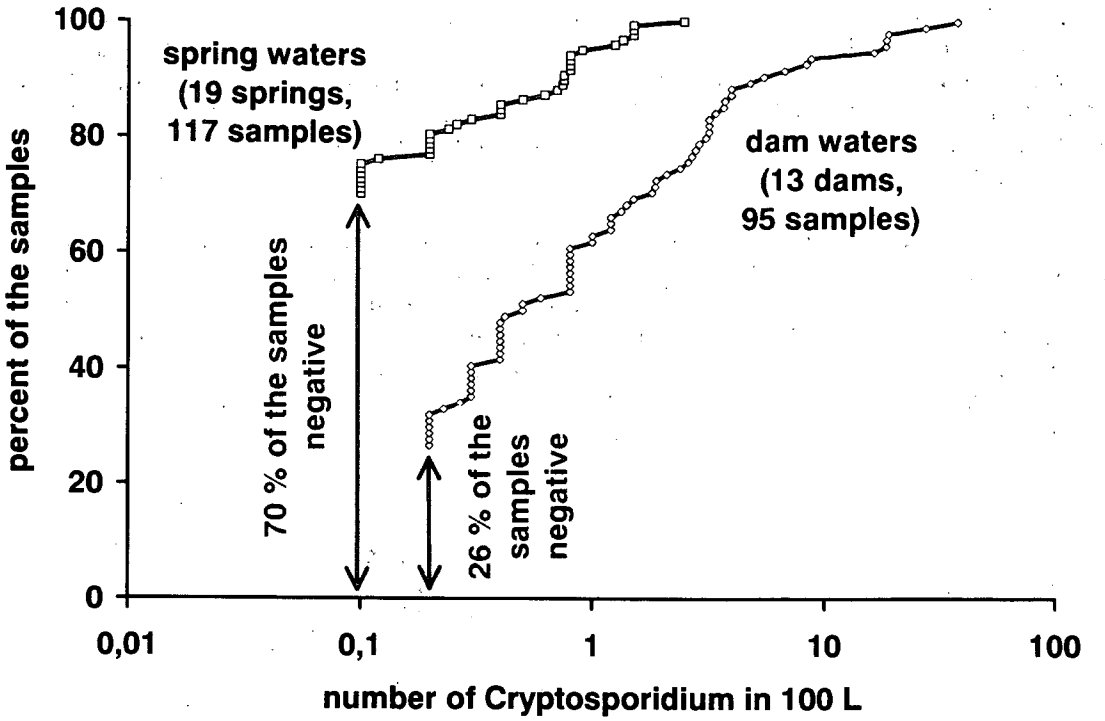

Figure 7: Screening on Cryptosporidium in dam and spring waters

Table 1: Overview of MF/UF-plants for drinking water treatment in Germany (8/2003) (Lipp and Baldauf, 2003)

Site	Capacity, m³/h	Source water	Start-up	Membrane type
Neckarburg	70	Carstic spring	9'1998	Aquasource
Hermeskeil	140	Spring + Dam	2'1999	X-Flow
Sundern	250	Sorpe Dam	3'2001	X-Flow
Marmagen	45	Carstic spring	3'2001	ZENON
Denkingen	15	Carstic spring	6'2001	X-Flow
Neustadt / Saale	70	River	7'2001	X-Flow
Olpe	80	Well	8'2001	X-Flow
Calw	50	Spring	2'2002	X-Flow
Jachenhausen	72	Carstic spring	8'2002	Inge
Olef	600	Olef Dam	1'2003	X-Flow
Regnitzlosau	27	Well	1'2003	ZENON
Bad Herrenalb	36	Spring	2'2003	X-Flow
Miltenberg	80	Well	5'2003	ZENON
Kandern	50	Spring	3'2002	X-Flow
Lauterhofen	90	Well	5'2003	X-Flow
Waldberg	210	Spring	7'2003	ZENON
Roetgen	150 (pilot)	Dreilägerbach Dam	2'2001	X-Flow
	6000		planned	Not decided yet
Hof	Pilot phase	River	2001	X-Flow / ZENON

Measuring turbidity and particle counts as well as microbiological indicator parameters may be an excellent tool for the utilities to control and optimize the removal of parasites such as

Cryprosporidium and Giardia during the treatment process.

In Germany membrane filtration is used in public water supply since 1998. Table 1 gives an overview and some technical details about the plants, that have been put in operation since then.

However further research is needed to optimize ultrafiltration. For instance, a case study of the long term behavior of an ultrafiltration plant showed a considerable increase of the transmembrane pressure (TMP) as can be seen in Figure 8. In this case study chemically enhanced backwashes were carried out with hydrogen peroxide every 4 to 8 hours. In time intervals of 4 weeks chlorine has been taken instead. It is planned to change backwash chemicals to acid and base. Nevertheless chlorine is a much stronger oxidant, the application should be minimized, due to the formation of by-products leading to sewage polluted with chlorinated compounds.

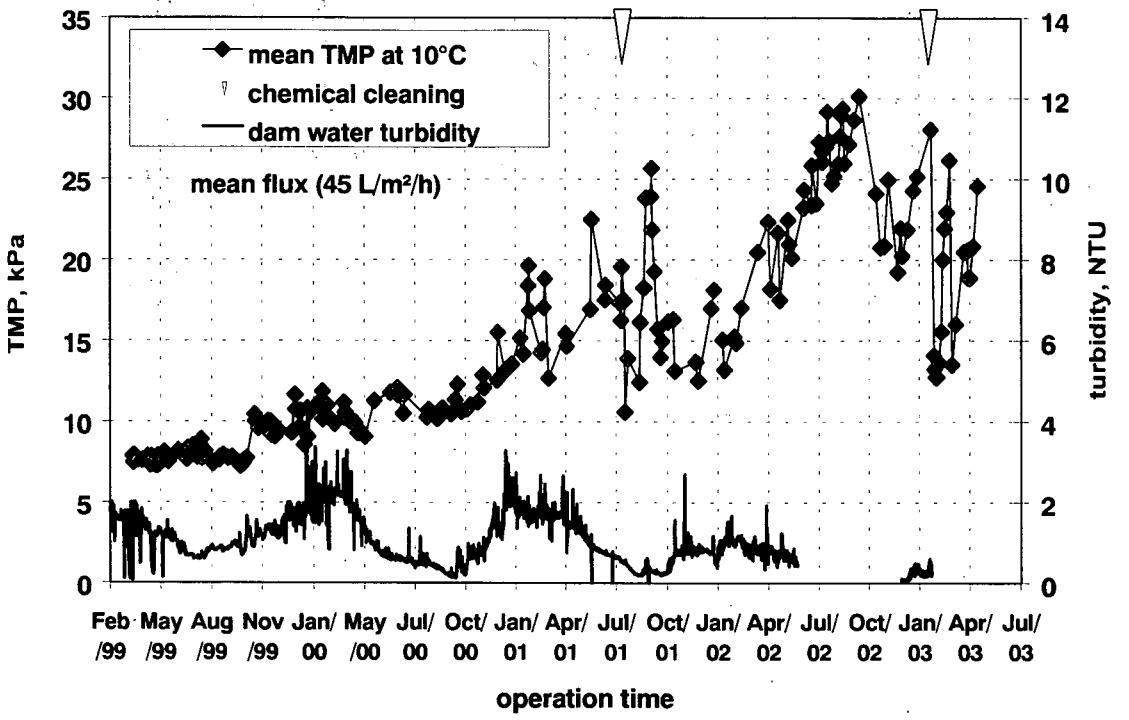

Figure 8: Case study: Increase of TMP versus time (Lipp et al., 2004)

Figure 9 shows results of realized improvements in full scale in five waterworks to enhance particle removal. The success of optimization was measured by particle counts for particle sizes in the 2 to 20 μm range. The particle counts were measured before and after optimization. The interval between both measurements of particle counts was up to 5 years.

The technological changes applied depend on the local situation. Utility 1 used three measures. First, ozonation was optimized to improve the ozone induced microflocculation. Second, to maintain a homogenous filter layer the backwash process was improved. Third, fluctuations in the throughput of the rapid filters were reduced. Utility 2 added a new flocculation and filtration step. Utility 3 replaced the filter material in the rapid filters. Utility 4 installed a direct flocculant dosage in the filter influent. Utility 5 decided to acquire an ultrafiltration. The efficiency for particle removal of the five different works can not be compared directly, since for utility 5 the particle count of the raw water is shown, whereas for utilities 1 to 4 particle counts of already pretreated water are plotted. Otherwise the efficiencies of utilities 1 to 4 would be higher.

As the results show, advanced as well as traditional methods supported the waterworks to enhance the particle removal even under consideration of cost and performance. Since a lot of waterworks are in operation already, optimization of existing processes is often more cost effective than building a whole new plant.

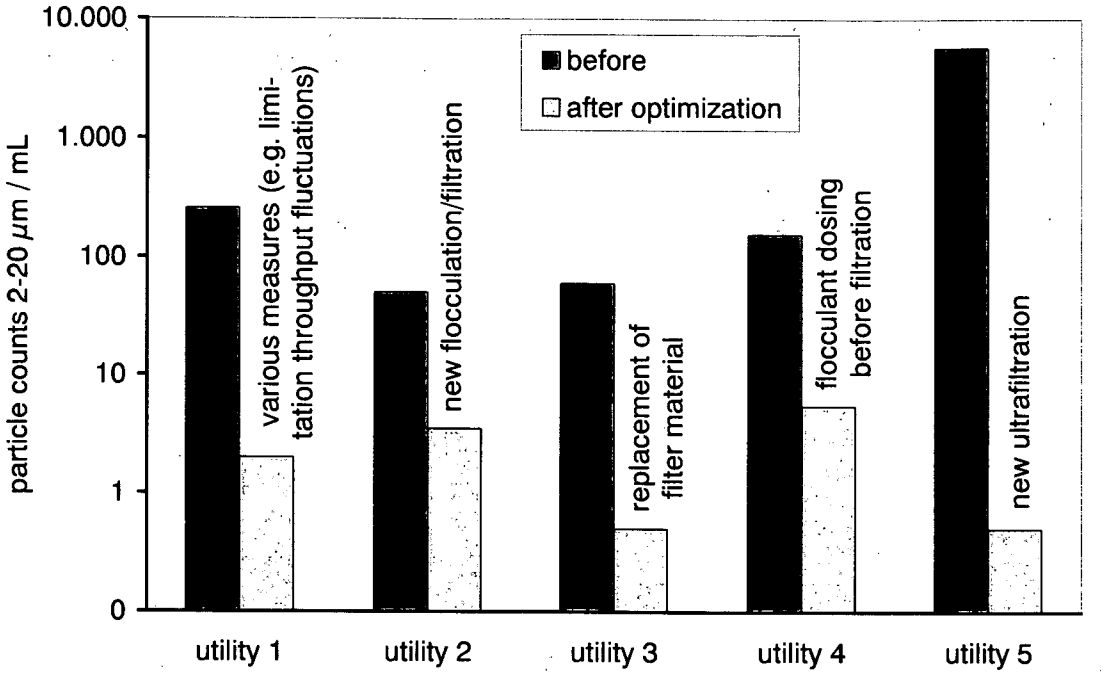

Figure 9: Examples for full scale optimizations to enhance the particle removal

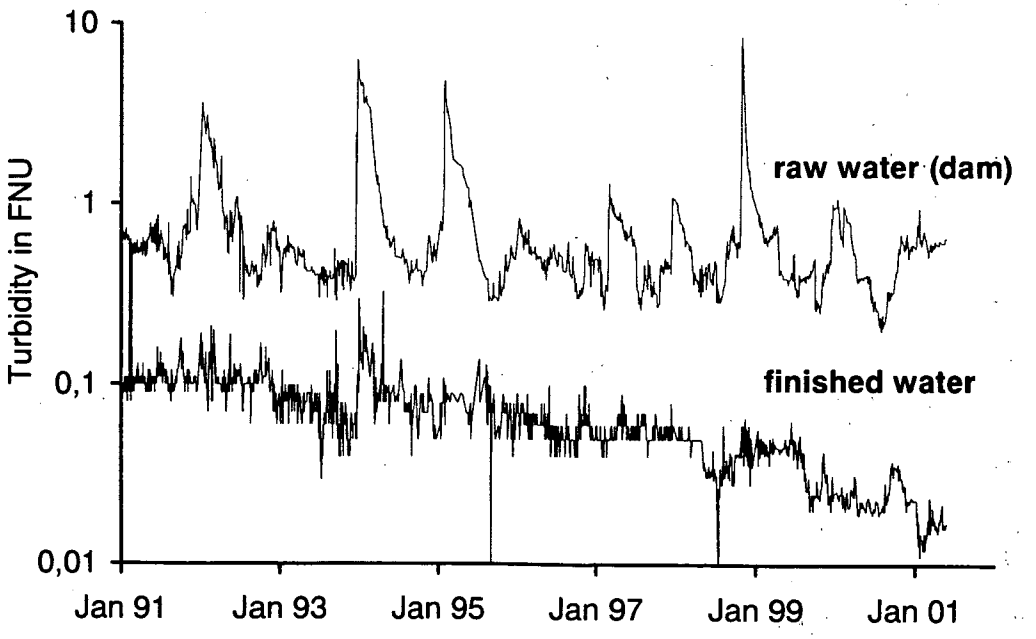

Figure 10: Example for full scale optimization by improving the traditional treatment

Further improvement of particle removal may be achieved in waterworks even at low turbidity

as shown in Figure 10. The waterworks for reservoir water treatment uses a traditional treatment consisting of steps to increase the hardness, ozonation, flocculation, rapid sand filtration and disinfection. Optimization of this conventional treatment process led to a drop of turbidity in the finished water from 0.1 FNU to less than 0.05 FNU and showed a more stable and much safer finished water even at high turbidity situations.

DISINFECTION

Due to the protection of the catchment areas many groundwater sources already meet the microbiological requirements of the drinking water standard. This means the water is free from coliforms or other pathogens. Therefore, approximately 60 % of the drinking water in Germany is distributed without disinfection. Waterworks operating with a disinfection step use mostly chlorine. In general, the chlorine dosages in the waterworks is low and range between 0.2 and 0.5 mg/L. A 1999 survey of some 1000 samples taken at 144 sampling points in distribution systems of 23 waterworks showed, that in most samples the THM-concentrations were below 50 µg/L (Fig. 11). A THM-concentration of 50 µg/L, measured at the consumers tap, is the limit of the German Drinking Water Regulation and 100 µg/L the parametric value of the European Union for water intended for human consumption. An increasing part of the waterworks replace chlorine with chlorine dioxide or with UV-irradiation to prevent the THM-formation.

If the groundwater meets the microbiological standards and the distribution system is in a good condition a safety chlorination may be dispensable. An example for switching from a distribution with chlorine residual to a distribution without residuals in full scale is given in Fig. 12. Approximately two weeks after chlorination was stopped, the heterotrophic plate counts (HPC, 20 °C, 2 days) increased. Continuing the water supply without chlorine, the HPC dropped down after approximately one month and remain constant to nearly < 5 cfu/mL. This is due to the formation of a different biofilm in the distribution network.

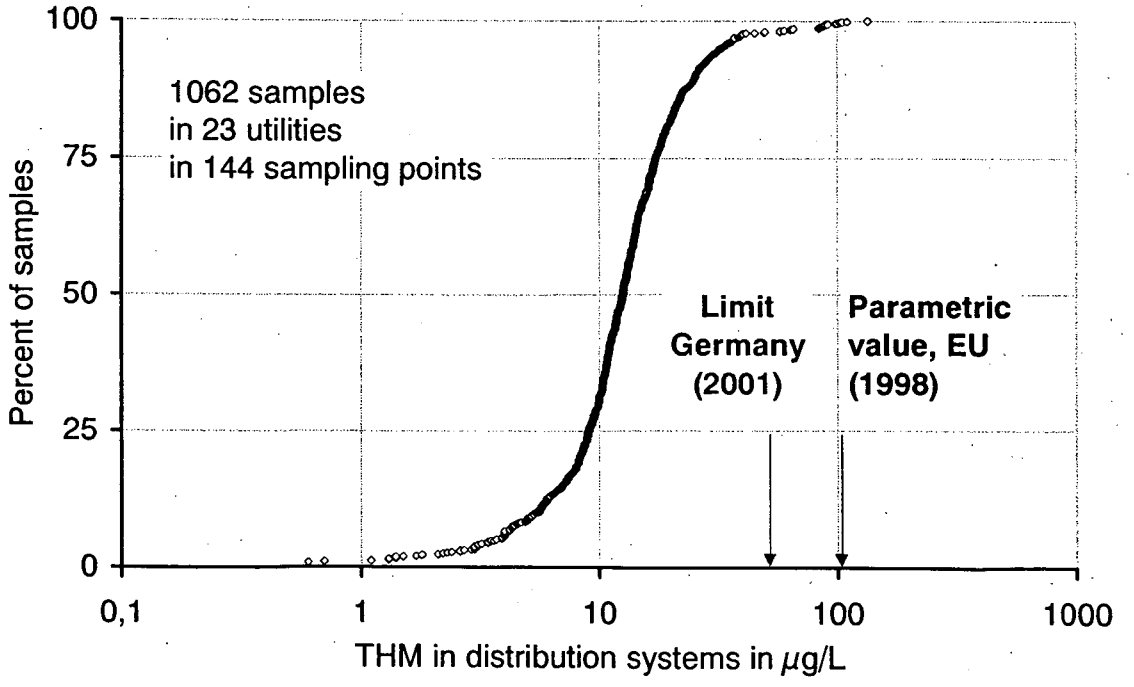

Figure 11: Survey on THM-concentrations in distribution systems

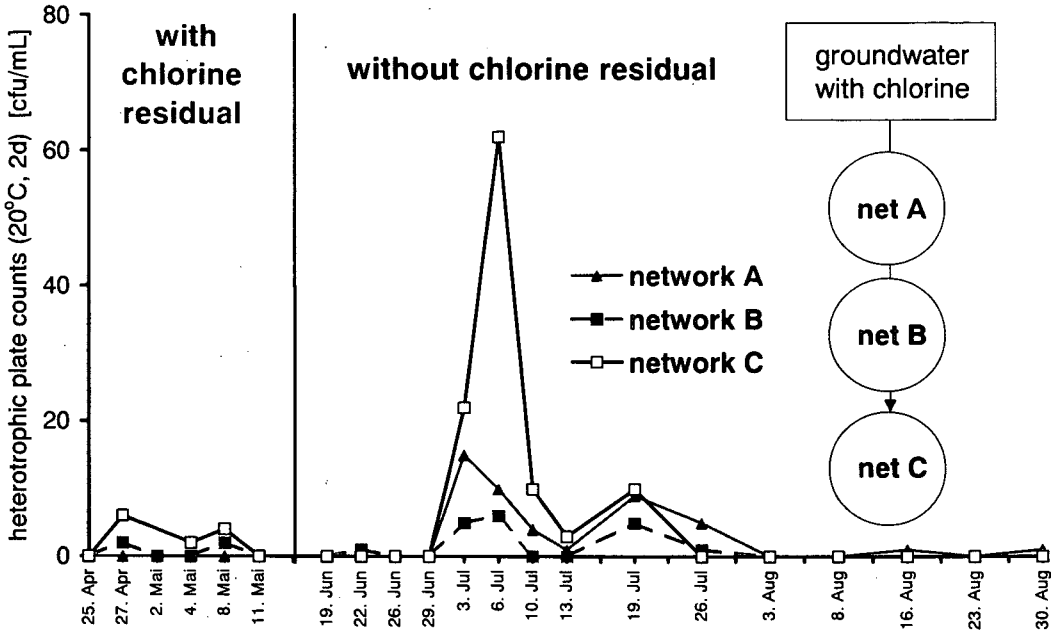

Figure 12: - HPC in distribution systems with and without chlorine residual (Hambsch, 1999)

CONCLUSIONS

The general philosophy for the waterworks in Germany to produce a fresh and safe drinking water is to establish a multiple barrier system. This concept covers three levels. Level one requires the protection of the raw water sources by stringent regulations and their control. On level two the treatment technology and operation should base on a suitable, site specific concept to produce a high quality drinking water even at possible quality changes of the raw water. Level three requires a careful maintenance of the distribution system. Only the consideration of all levels guarantees to supply the consumer with a safe and high quality drinking water.

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FATE OF SANITARY INDICATORS IN TREATED WASTEWATER

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ABSTRACT

Treated wastewater quality standards need to be reviewed to improve the safety of water systems. However, much remains to be clarified concerning the fate of sanitary indicators in natural water. This research examines this topic.

For clarifying the fate of bacteria as indicators of sanitation, we conducted experiments using an experimental channel made of stainless steel. The parameters of the channel were changed for each experiment, namely the bed of the channel, temperature, flow rate, chlorine reduction, and inclination. The floor of the channel was stainless steel, gravel, or gravel with biofilm attached by secondary effluent run through the channel for about a month. We measured E. coli, coliform bacteria by desoxycolate and Chromocult, standard plate count, and general water quality indicators at the beginning and end of each experiment.

The results showed that the removal ratio of E. coli was almost 100% in all cases, though the removal ratios of other indicators were affected by temperature, chlorine reduction, and so on.

KEYWORDS

Coliform Bacteria, E. Coli, channel, disinfection

INTRODUCTION

Sewerage services have improved public health and preserved water qualities in public water bodies. The percentage of sewered population has reached 65.2% in Japan (Ministry of Land, Infrastructure, and Transportation (MLIT), 2003), and some sewage treatment plants are now located upstream of intake facilities. The importance of the sewage system is growing as its diffusion increases, making it necessary to consider space for siting, water recycling or reuse, and so on. Water quality must be kept safe and sanitary indicators monitored. However, the fate of coliform group, which is used as a sanitary indicator for treated wastewater in Japan as shown in Table 1, in natural water is not well understood. For example, it is well known that coliform group often increases after disinfection (e.g. T. Sumitomo, et al., 1993), so coliform group may not be suitable as a sanitary indicator. Indeed, for drinking water, the sanitary indicator has been changed from coliform group to E. coli.

To provide a reference sanitary indicator for treated wastewater, we surveyed in our laboratory the fates of some sanitary indicating bacteria in differently disinfected treated wastewaters, and in different water bodies receiving treated water flows. This report presents the results of some investigations we conducted using the experimental channel to clarify the

fate of sanitary indicators in natural water.

METHODS

This investigation focused on whether sanitary indicating bacteria in disinfected treated wastewater increase or decrease in natural water, because it was reported that indicating bacteria which decreased by chlorine disinfection tended to increase again from 100 to 200 hours later in cases of lower concentration chlorine disinfection (T. Hatatsu, et al., 1999). On the other hand, it was reported that indicating bacteria in not disinfected treated wastewater decreased after passing through an experimental channel (T. Hatatsu, et al., 2001). We therefore measured some indicating bacteria in disinfected wastewater after passing through the experimental channel.

Figures 1 and 2 show the experimental channel. Numbers in squares in Fig. 1 show the points where depths were measured. The experimental channel consists of a chlorine mixing tank, chlorine reduction tank, recycling tank, feeding pumps, and channel. The channel is

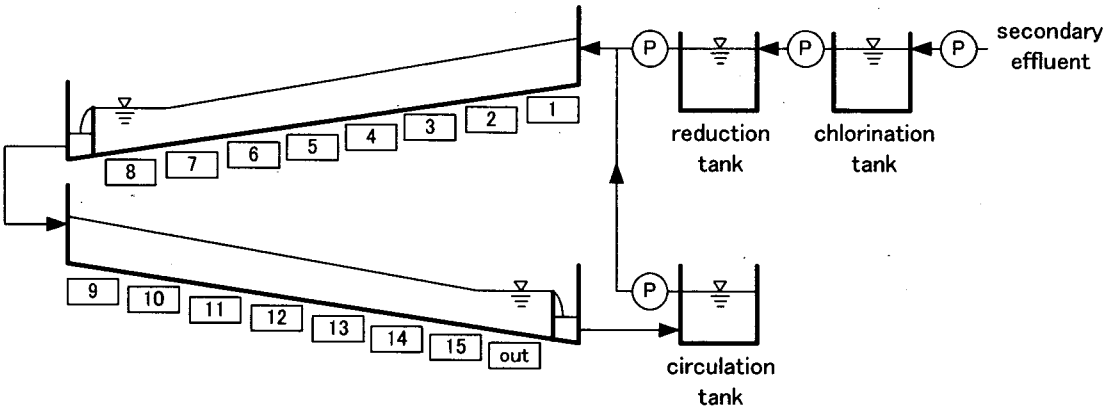

Fig. 1 The experimental channel

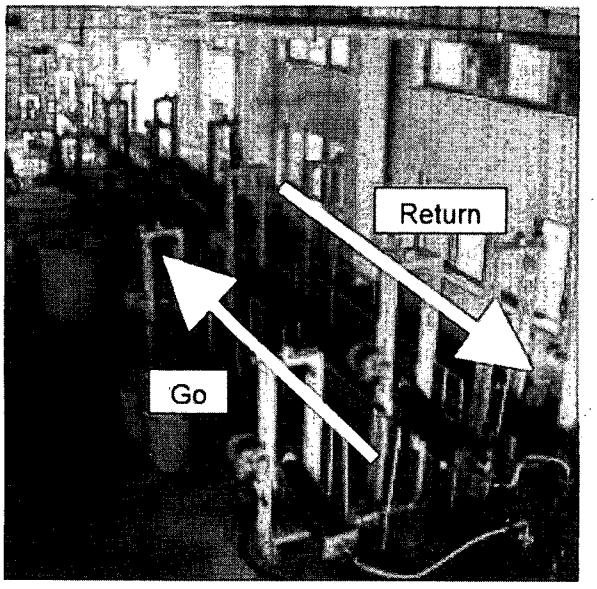

Fig. 2 The experimental channel

made of SUS, and is connected in series with two channels of 0.2 m wide and 30 m long (total length 60 m). Sample water can be passed through the channel either once, or cyclically by using a circulating pump. The inclination of the channel can be set freely.

The sample water was chlorine disinfected treated actual wastewater, which was taken from the pilot plant (10 m3 volume) of a conventional activated sludge process, or that reduced by sodium thiosulfate. Chlorine dosage was 0.5 mg/L and contact time was 15 min.

The indicating bacteria measured were coliform bacteria, E. coli, and standard plate count. E. coli was measured by Chromocult Coliform Agar which could distinguish E. coli by color, reflecting the activity of β-galactosidase and β-glucuronidase. Coliform bacteria were measured by desoxycholate agar and Chromocult Coliform Agar. Table 1 shows the indicating bacteria in Japan. Water temperature, pH, DO, COD, SS, nitrogen, and phosphorus were measured. Samples were taken from "1" in Fig. 1 at the beginning of each experiment and from 120 to 150 hours later, because it was shown that decreased coliform bacteria increased about 100 hours after chlorine disinfection (T. Hatatsu, et al., 2001).

Table 1 Sanitary indicators for water in Japan

Drinking water

indicator	unit	standards
standard plate count	[CFU/mL]	100
E. coli	[MPN/100mL]	N. D.

Bathing water

indicator		classification	unit	standards
Fecal coliform	good	water quality AA	[CFU/100mL]	N. D.
		water quality A	[CFU/100mL]	100
	fair	watar quality B	[CFU/100mL]	400
		water quality C	[CFU/100mL]	1000

Technical standards for treated wastewater

indicator	unit	standard
coliform bacteria	[CFU/mL]	3000

The conditions of the experimental channel are shown in Table 2. The channel bed was made of SUS, gravel, or gravel with biofilm. In the case of SUS, the experimental channel was cleaned using tap water before each experiment. In the case of gravel, the experimental channel and gravel were cleaned using tap water and the biofilm attached to gravel was removed before each experiment. In the case of gravel with biofilm, after cleaning the experimental channel and gravel, not disinfected treated wastewater of 15 L/min was passed through the channel one way for about one month, and biofilm was attached.

RESULTS

Table 2 shows the results. SS decreased in every case. It had been assumed that SS would be more in RUN 6 and 7 because it had turbulent flow and SS was raised, but SS decreased to the same level. Decreased SS seemed to lower during the period of the experiment from 120 to 150 hours. Exceptionally, SS did not decrease in the case of gravel bed with biofilm. The reason for this is thought to be that biofilm peeled off from the gravel with SS during sampling.

Table 2 The conditions of the experimental channel and the results of the experiment

			RUN 1		RUN 2		RUN 3		RUN 4		RUN 5		RUN 6		RUN 7		RUN 8	
			before	after	before	after	before	after	before	after	before	after	before	after	before	after	before	after
Conditions of experiment	channel bed				SUS								gravel				biofilm	
	reduction of chlorine		×		×		○		×		○		×		×		×	
	flow rate	[L/min]	15		15		15		15		15		100		100		15	
	inclination	[‰]	2.33		2.33		2.33		2.33		2.33		2.33		6.67		2.33	
Water qualities	water temperature	[°C]	10.3	8.4	25.4	23.5	21.8	21.4	13.8	9.9	24.9	23.9	12.7	11.5	13.2	13.3	17.4	22.7
	pH		6.8	7.8	6.4	7.5	7.1	6.9	7.6	7.1	6.5	6.0	6.5	7.5	6.5	7.6	6.2	5.4
	DO	[mg/L]	5.3	10.6	6.2	8.1	8.3	4.7	8.8	11.2	2.7	4.2	7.6	8.0	7.7	6.6	5.0	4.4
	free chlorine	[mg/L]	0.11	0.06	0.08	0.07	0.07	0.04	0.15	0.09	0.00	0.05	0.10	0.04	0.11	0.09	0.08	0.08
	total chlorine	[mg/L]	0.14	0.08	0.10	0.07	0.10	0.09	0.23	0.11	0.21	0.10	0.14	0.11	0.12	0.11	0.14	0.12
	COD_{Cr}	[mg/L]	52	54	28	8	59	21	40	54	37	14	51	17	20	31	26	21
	SS	[mg/L]	18.5	0.3	8.8	1.1	7.6	1.4	2.6	1.7	5.4	1.2	11.8	0.6	6.6	2.4	8.0	7.0
	T-N	[mg/L]	15.0	12.7	18.1	19.2	18.0	19.0	13.5	21.8	22.0	25.4	15.2	17.0	14.8	15.2	23.9	38.3
	NH_4-N	[mg/L]	1.8	0.1	0.2	0.0	0.1	0.1	1.0	0.1	0.2	0.1	0.3	0.1	0.1	0.1	0.1	0.6
	NO_2-N	[mg/L]	8.6	4.4	0.1	0.0	0.0	0.1	5.6	4.8	0.1	0.2	3.9	1.4	11.3	0.0	0.2	0.1
	NO_3-N	[mg/L]	1.7	5.9	22.9	18.9	12.6	17.2	3.7	12.3	16.5	16.4	7.1	14.5	2.0	13.7	20.9	33.4
	NO_X-N	[mg/L]	10.3	10.2	23.0	18.9	12.6	17.2	9.3	17.1	16.6	16.6	10.9	15.9	13.2	13.7	21.1	33.5
	T-P	[mg/L]	1.68	1.38	1.82	1.75	1.91	2.02	1.61	1.80	1.97	1.25	1.69	1.50	1.55	1.39	2.13	3.28
	PO_4-P	[mg/L]	1.23	1.25	1.75	1.71	1.70	1.76	1.42	1.67	1.68	1.72	1.36	1.50	1.39	1.47	1.60	2.85
Sanitary indicators	E. coli	[CFU/mL]	138	1	97	0	41	1	28	0	66	1	55	2	83	2	32	1
	coliform bacteria (chromo)	[CFU/mL]	2,125	24	2,810	825	1,935	1,535	1,945	66	4,670	2,050	2,040	113	2,230	107	1,085	633
	coliform bacteria	[CFU/mL]	87	11	585	215	1,035	420	206	18	1,035	845	115	13	233	49	171	1,650
	standard plate count	[CFU/mL]	5,450	320	2,225	1,280	8,350	595	27,600	2,940	3,550	4,700	8,450	620	21,450	835	2,260	2,660
Removal ratios	E. coli	[%]	99.3		100.0		98.8		100.0		99.2		97.3		97.6		98.4	
	coliform bacteria (chromo)	[%]	98.9		70.6		20.7		96.6		56.1		94.5		95.2		41.7	
	coliform bacteria	[%]	87.9		63.2		59.4		91.5		18.4		89.1		79.2		-864.9	
	standard plate count	[%]	94.1		42.5		92.9		89.3		-32.4		92.7		96.1		-17.7	

COD_{Cr} decreased in many cases as well as SS, though COD_{Cr} of RUN 1, 4, and 7, in which the water temperature was low, increased. COD_{Cr} did not seem to be decomposed by microorganisms because of low temperature, but the reason for the increase is not clear.

Concerning Nitrogen and Phosphorus, there were not obvious differences. NO_3-N increased in almost all cases and Nitrogen was nitrified in experimental process.

Generally, water in the experimental channel was in aerobic condition, and organics tended to be decomposed.

Concerning sanitary indicating bacteria, coliform bacteria and standard plate count were different in each case, although more than 97% of E. coli was removed in all cases. First, comparing RUN 1 (Ave. 9.4℃) and RUN 2 (Ave. 24.5℃) at different temperatures, the removal ratios were 87.9% for coliform bacteria by desoxycholate, 98.9% for coliform bacteria by chromocult, and 94.1% for standard plate count in RUN 1, and were 63.2%, 70.6% and 42.5% in RUN 2. It was reported that coliform bacteria were related to temperature in river investigations (K. Mitarai, 1983), and coliform bacteria increased in physiological salt solution at 20℃ (including a small amount of culture medium), but decreased in that at 4℃ (T. Hatatsu, 1999). The results of this investigation, in which coliform bacteria and standard plate count were at higher temperature, supported the previous finding.

The differences of sanitary indicating bacteria caused by whether chlorine was reduced or not were observed. Comparing RUN 2 with RUN 3, the removal ratios of coliform bacteria by both desoxycholate and chromocult were lower in the chlorine-reduced case (RUN 3). Comparing RUN 4 with RUN 5, the removal ratio of indicating bacteria was lower in the chlorine-reduced case, though the effect of chlorine reduction was not so obvious because of different water temperatures. The differences of removal ratios of indicating bacteria between RUN 4 and RUN 5 were more than the differences between RUN 1 and RUN 2, which were different only in temperature, so the differences between RUN 4 and RUN 5 depended mainly on whether chlorine was reduced or not. However, concerning standard plate counts, the removal ratio of RUN 3 in which chlorine was reduced was more than that of RUN 2, and the standard plate count of RUN 5 increased. The reason for this is not clear.

In the case of gravel with biofilm, the removal ratios of sanitary indicating bacteria except for E. coli were relatively low, and the decomposition of indicating bacteria by biofilm could not be observed. SS after the experiment of RUN 8 was higher than in any other case, and it was thought that the biofilm peeled from the gravel when the water was sampled. As a result, coliform bacteria increased to 10 times and coliform bacteria were thought to attach to SS.

SUMMARY

1) When chlorine disinfected treated wastewater was passed through the experimental channel, sanitary indicators were affected by the water temperature and chlorine reduction. On the other hand, the effects of channel bed, flow rate, and inclination could not be observed in this study.
2) The increase of coliform group could not be observed in this study. The effects of the decrease of coliform group caused by adsorption to gravel or being preyed upon were thought to be greater.
3) The decrease of sanitary indicators in the case of gravel with biofilm could not be observed though such decrease had been expected due to being preyed upon by biofilm. The reason was supposed to be the effect of SS raised from biofilm.

4) The removal ratios of E. coli were more than 97% in any cases.

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The BMBF Program "Decentralized (Alternative) Water Systems"

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FORSCHUNGSZENTRUM KARLSRUHE

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BACKGROUND:

The projects funded by the BMBF/PTWT+E concerning decentralized (alternative) water systems are based on an announcement in the "Bundesanzeiger" (Federal Gazette) of June 27, 2001.

All the drafts (112 in total) were surveyed on behalf of the BMBF by an external committee consisting of experts in water management, associations, universities, and members of industry. The announcement itself was made in accordance with the BMZ/GTZ project "ecosan". The levels of international development, technical feasibility, and administrative requirements were compiled from two studies carried out by the University of Witten-Herdecke and the University of Munich.

Especially with the international projects, we wish to contribute to a more conscious and sustainable use of water, a resource that cannot be replaced. Accordingly, these projects contribute to the ambitious aims of the Sustainability Summit of Johannesburg, which was to halve, by the year 2015, the proportion of people who are unable to reach or afford safe drinking water and do not have access to basic sanitation.

The BMBF research program is mainly designed to combine and to improve existing components. Apart from the reduction of the drinking water consumption key aspects are to decouple materials and water flows such that recovery of nutrients and energy will be possible and economically efficient.

Subjects of investigation are: Anaerobic waste water treatment, membrane filtration, processes close to nature, reuse of gray water and rainwater, separation vacuum and compost toilets, winning of biogas and decentralized power stations, production of compost and fertilizers, economic, socio-cultural, and legal aspects.

Concerning the implementation and dissemination of the research results an adequate contribution from German private companies as well as from the foreign partners is required. (The system of project funding does not allow a direct funding of foreign partners.)

CURRENT PROJECTS:

VIETNAM:

Topic:

Closing of agricultural nutrient cycles via hygienically harmless substrates from decentralized water systems in the Mekong delta

University of Bonn:

working group materials flows	Dr. J. Clemens
working group hygiene	Dr. Th. Kistemann
working group sociology	Prof. Dr. Th. Kutsch
working group agricultural ecology	Prof. Dr. M. Becker
working group agricultural water management	Prof. Dr. A. Rieser

University of Bochum:

working group drinking water	Prof. Dr. H. Stolpe

Level of knowledge:

About 17 million people are living in the Mekong delta (40,000 km²). The population density is twice as high as in Germany. The delta is mainly used for the growing of rice, vegetables, and fish farming. Less than 50 % of the total population have access to fresh water, in rural areas less than 10 %. Instead of drinking water, people use collected rainwater (pathogenic germs) or water from uncontrolled wells (chemicals for use in agriculture, seawater intrusion)

Main activities:

In the first part of this project the soils, groundwater, water and materials flows, and the agricultural use of two different areas in the Mekong delta will be studied in detail.

The varying demands of soils for fertilizer/sludge or humus/compost will form the basis on which the most suitable waste water concept will be worked out.

Concerning drinking water, the disinfection with soil filtration, solar energy and the sustainable abstraction of groundwater will be examined.

Comment on project funding:

The Mekong delta is considered typical for many territories of South Asia:

alternation between flood and demand for irrigation

pollution of the raw waters (groundwater, surface water)

rural areas which are intensively used for agriculture

Construction and maintenance of drinking water treatment and waste water treatment plants are expensive, especially in areas with low average income. The idea of this project is to adapt the

waste water treatment system directly to the demands of agriculture. This will increase the consumer acceptance and decrease the costs of the maintenance.

EGYPT:

Topic:

Improvement of the effluent quality of aerated lagoons (ponds) by membrane filtration

Institute for Technical Pollution Control	Prof. W. Hegemann
National Research Center	Prof. Abdel Shafy

Level of knowledge:

Lagoons are widely spread because of the simple and cost-saving construction and maintenance. However, the rate of degradation and the retention of bacteria and germs is limited compared to activated sludge plants. Strictly speaking, direct use of the effluents for irrigation purposes is not possible.

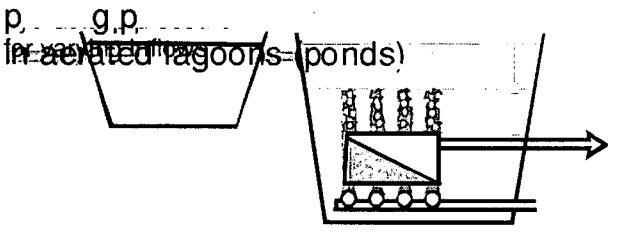

Figure 1: sketch of the pilot plant

Main activities:

A pilot plant will be constructed and transferred to an existing waste water treatment plant in a village near Cairo. The pilot plant will serve for about 500 population equivalents.

The device will be optimized to reduce water evaporation, to increase retention of pathogenic germs, the operation safety, and to reduce the costs of maintenance.

After membrane filtration, the treated waste water is intended to be reused for irrigation or as industrial process water.

For applications in Germany or Eastern Europe, where lagoons are frequently met, operation conditions for N- and P-removal will be studied. The treated waste waters should then be discharged into receiving water bodies or infiltrated into the ground.

Comment on project funding:

In the case of success, this project will contribute to the improvement of existing simple waste water treatment plants. It is designed to save rare drinking water resources and reduce the costs for fertilizers. Egypt was chosen as location as it is considered typical for all semi-arid climates.

The operation conditions with N- und P-removal will allow to optimize existing lagoons (ponds) in Germany and Eastern Europe, respectively.

TURKEY:

Topic:

MODULAARE - Integrated modules for high-efficient waste water treatment, waste treatment and recovery of energy in tourism resorts

partners:

AT association	Dr. U. Theilen
University of Stuttgart	
Department of Waste Water Technology	D. Steinbach
Department of Municipal Solid Waste Management	Mrs. A. Schultheis
Iberotel Sarigerme Park (TUI)	Heinz H. Fugger

Level of knowledge:

The materials flows in (tourist) hotels are extremely high::

waste/hotel	up to 2.5 kg/guest day
average/Germany:	about 0.5 kg/inhabitant day
drinking water consumption/Hotel	up to 1.200 L/guest day
average/Germany:	< 130 l/inhabitant day

Proper recycling management is generally not applied in hotels or tourist resorts.

Sarigerme Park Hotel situated on the Turkish Aegean coast about 372 beds and was selected for the following reasons:

there is sufficient place for pilot plants

the hotel provides the necessary technical equipment to support the research program.

the hotel is connected to a municipal waste water treatment plant. In the case of operation troubles or reconstruction measures there will not occur any problems.

the hotel has been granted different environmental awards and was certified according to DIN EN ISO 14001. This shows the commitment of the hotel management to a sustainable tourism.

Main activities:

A large closed-loop recycling waste water and solid waste is intended to be achieved by the activated membrane reactor the fermentation module.

The membrane module will produce industrial process water. Its suitability for irrigation, fertilization, and the hotel laundry will be investigated.

Cut grass, kitchen garbage and the surplus sludge will be treated in the fermentation reactor. This module will be optimized in terms of amount of produced biogas, quality of compost, and pre-treatment of the input materials.

A concept to make use of the biogas (i.e. decentralized power station) will not be realized at the moment.

Comment on project funding:

Since the tourism industry is an important economic factor in Germany, we are particularly responsible for supporting sustainable tourism. In a lot of touristic areas the situation is quite similar.

Due to the modular concept, an adaptation to various places and climatic zones seems to be easily realizable.

Brazil:

Topic:

Decentralized water supply and waste water treatment combined with recovery of nutrients and energy under consideration of hygienic aspects for Piracicaba

Partners

Fraunhofer Gesellschaft	Dr. Sternad
Universidade Metodista de Piracicaba	A. Nascimento

Level of knowledge:

Only 9.6 % of all South American bigger cities (> 50,000 inhabitants) treat their waste waters. In the city of Piracicaba (320,000 inhabitants) about 35 % of the waste waters are treated in 45 usually smaller treatment plants. The waste water is frequently treated in open ponds, so that the dengue fever and other tropical diseases have spread.

Solid waste is deposited on unsuitable dumps, no recycling has been applied up to now.

Main activities:

Waste Water:
Improvement of waste water treatment in Piracicaba.
- A study will be carried out regarding the optimization of existing treatment plants. They will be evaluated concerning the production of biogas, production of N-, P-fertilizers, disinfection of the effluents.

Most of the existing waste water treatment plants start with an anaerobic stage. (target: optimization of the anaerobic reactor.)
Most of the plants apply an aerobic reactor as second step. At the biggest waste water treatment plant (Piracicamirim) it is intended to install a closed pilot reactor developed in Germany.
Waste:
- A concept for the separation, recycling of waste, and production of biogas will be worked out. A pilot plant for the production of biogas will be constructed on the campus.

Comment on project funding:

The city of Piracicaba is considered a promising location in Latin America. The region has a good reputation regarding its commitment to environmental protection. The first environmental associations were founded in Piracicaba. So we are looking forward to finding highly motivated local authorities.

The concept developed by FhG strongly considers the local infrastructure which are characterized by a lot of small (decentralized!) plants, no space for enlargement, and frequently the above mentioned two-stage construction.

With the help of two pilot plants it is intended to show an economically efficient way to improve existing plants.

GHANA:

Topic:

Ecological recycling management at the Valley View University in Accra

Partners:

Ingenieurökologische Vereinigung e.V.	Dr. Geller
Bauhaus University of Weimar/ecological engineering	Prof. Dr. D. Glücklich
University of Hohenheim/Tropics center	Prof. Dr. J. Sauerborn
Valley View University	Dr. S. Laryea

Level of knowledge:

The Valley View University is biggest private university of Ghana (about 710 students, 50 lecturers/administra-tion), water supply is mainly managed by trucks because of the inefficient public supply, there's no utilization of rainwater or water-saving technologies, waste water is treated by old-fashioned methods, and the university will be enlarged (2005: about 1300 students)

Main activities:

The present concept for the enlargement of the university will be extended to an ecological master plan (subjects: urban development, transport; energy, water, and waste; social and cultural activities).

- Reconstruction of a building with water saving toilets, construction of a new building with water saving toilets, compost toilets, and utilization of gray water.

- Storage of rainwater in a cistern for irrigation

- Recycling of biowaste, compost, urine, ... in agriculture, production of biogas.

Comment on project funding:

This project addresses to a target group that is highly interested in new technologies. We expect this to be of great advantage to the implementation of the joint research results, because the graduates of the university will spread their acquired knowledge to their home countries.

It will be interesting to study the social acceptance and the technical advantages or disadvantages of different techniques (water-saving toilets, compost toilets...) applied at the same place.

The results of this cooperation will be incorporated into a new study course called "Community and International Development Studies" at the Valley View University.

CHINA:

Topic:

Semi-central Supply and Treatment Units for Urban Areas in China

Partners:

Technical University of Darmstadt	Prof. Dr. P.Cornel
Tongji University Shanghai	Prof. Gao

Level of knowledge:

In China 70-80% of the discharged wastewaters are untreated. 98% of the total amount of waste is disposed on the suburban areas or simply littered into the water bodies.

Especially in rapidly growing mega-cities these deficits lead to serious environmental problems like for example the overuse of water resources or the contamination of soil, ground-water and surface water.

Main activities:

Within this project new technical solutions (so-called semi central units) for an integrated supply and treatment system (water, wastewater and waste) will be developed. Semi central here means a dimension that exceeds single houses or buildings, but that clearly differs from a conventional central system. The best technical alternatives and unit sizes for different types of urban areas will be worked out and compared with existing systems.

Comment on project funding:

This project is the only one designed for rapidly growing urban areas. We think that the problem of the most effective size of waste and waste water treatment plants has not yet been satisfyingly resolved regarding the recovery of energy and raw materials.

LATIN AMERICA:

Topic:

Aqua Latina (www.aqua-latina.info)

Partners:

Fraunhofer Gesellschaft	Prof. Dr. R. Kümmel
ARÖW Ltd.	Dr. Hafkesbrink

Level of knowledge:

There's nearly no waste water treatment in rural areas of Latin America. In many places, the drinking water supply is considered as endangered or even critically endangered. 30 % of all cases of death of children and 95 % of all hospital stays of children are caused by unsafe drinking water.

Main activities:

In the first part of this project an internet based platform will be provided. More than 20 small or medium-sized companies will be involved in this project. These companies will provide technical

information, routines for the calculation and evaluation of different municipal water and waste water systems.

In the second part of the project, two concepts (water, waste water, recovery of nutrients and energy, reuse of sludge) will be implemented in two different cities. The results will also be spread via the internet based platform.

Comment on project funding:

We think that water and waste water technologies developed by high industrialized countries cannot be brought into developing or threshold countries without any adaptation to the local requirements, socio-cultural needs, and technical possibilities. Furthermore, we think that decentralized systems are more convenient for countries without a centralized water supply and sewer system. In Germany, it's rather the smaller companies which provide appropriate technologies for these purposes. These companies will be supported in their effort to go to foreign countries.

ALGERIA:

Topic:

Decentralized recycling of waste water from sewers for arid urban areas

Partners:

University of Witten-Herdecke	Prof. Dr. K-U. Rudolph
GTZ Gesellschaft für Technische Zusammenarbeit	Dr. D. Gomer

Level of knowledge:

In arid urban areas green belts can only exist if they are continuously irrigated. Especially in arid areas green belts are obligatory for the local climate. If they are missing, the resulting dust content of the air is intolerably high.

Main activities:

Within this project the controlled recovery of raw waste water or waste water after little pretreatment will be studied from water technological, hygienic, geological, topographic and climatic points of view.

The following three figures are examples for the ideas that will be followed within this project.

Protection of erosion-endangered slopes by irrigation with raw waste water

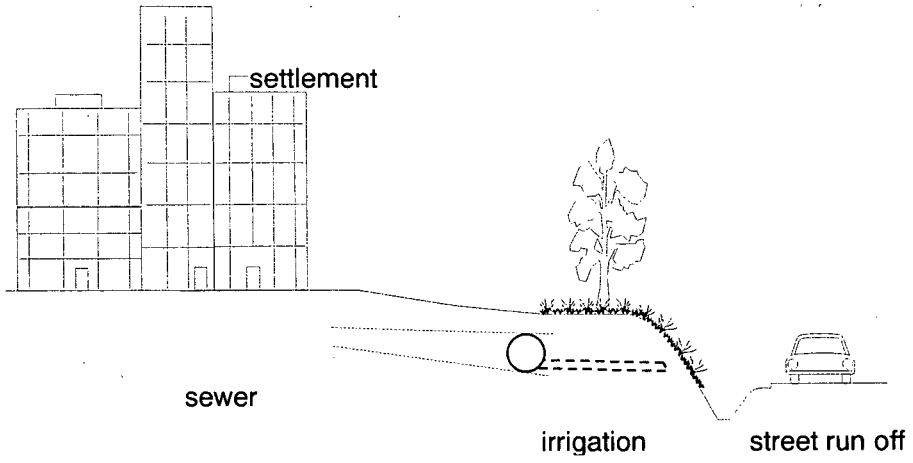

Figure 1: Irrigation of raw waste water from higher situated sewer systems (erosion-endangered areas)

- Creation of new green belts between lanes of roads by filtrated waste water

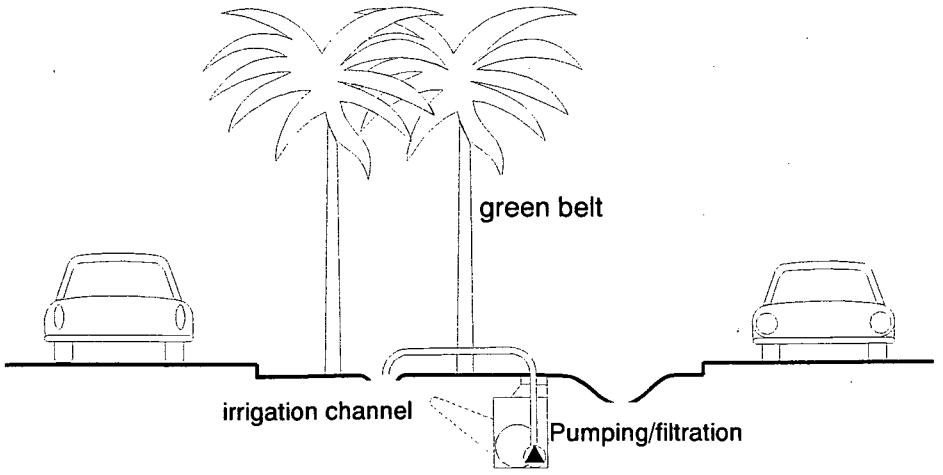

Figure 2: Irrigation of green belts between lanes by filtrated waste water

- Irrigation of green areas by waste water after sedimentation

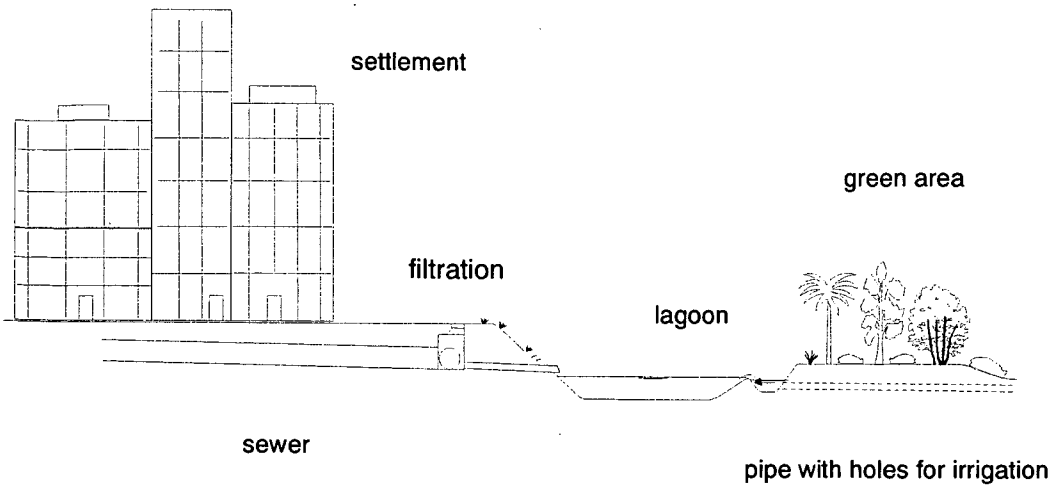

Figure 3: Irrigation of green areas after sedimentation in lagoons.

Comment on project funding:

Many people in developing countries even use raw waste water for agricultural purposes. This causes enormous hygienic and ecological problems. Within this project we try to develop a simple method to create green areas in arid cities in order to improve the local climate without causing hygienic problems for the population.

CHINA/TANZANIA:

Topic:

Obtaining of water by exchange of radiation

Märkische Fachhochschule Iserlohn	Prof. Dr. D. Ihrig
Koch Anhängerwerke Ltd.	Christian Koch

Level of knowledge:

A method to obtain drinking water independent from the ground-water table is to use the humidity of the air. Most devices which have been developed so far are inefficient, very expensive, and difficult to control, respectively.

Main activities:

A new concept to obtain drinking water from the humidity of the air will be studied. The problem of the energy need will be solved by the exchange of radiation with the atmosphere. The control of the device will be managed without any difficult electronic control units.

Comment on project funding:

One big task for the future will be to develop alternative methods to gain and store freshwater for drinking water supply. This project will be one part of Germany's contribution to fulfil the contracts

of Rio and Johannesburg. The aim is to reduce by half the amount of people without access to safe drinking water until 2015.

At the moment the obtaining of water from the humidity of the air is quite expensive. Numbers raise from 10 to 60 €/m³. On the other side, the costs for sea water desalting are more and more decreasing (1 - 2 €/m³). However, sea water desalting is only useful in costal areas and is managed by fossil energy. It seems to be feasible to reduce the costs of the new method effectively.

SOUTH AFRICA:

Topic:

"Water House" Makuleke, near to the Krueger National Park

University of Potsdam Dr. K. Soyez

University of Venda, South Africa

EBT Ltd.

AHK Deutsch-Südafrikanische Außenhandelskammer

Level of knowledge:

The supply with fresh water, mainly managed by trucks, in the village of Makuleke is completely insufficient, and furthermore the water delivered is of bad quality. The abstraction of raw water by wells cannot be managed continuously due to the changing ground-water table. There is no distribution system.

Main activities:

A so-called "water house" designed for all water-related activities will be constructed

This includes a survey on the current status of the drinking water supply, climatic conditions, the hygienic conditions, socio-cultural aspects. Currently it is planned to include compost toilets, rainwater storages, constructed wetlands, and reuse of the sludge from waste water treatment in the agriculture.

Comment on project funding:

This project has been designed to improve the hygienic situation of rural areas in the third world. We support this project because a funding system has been worked out to operate the water house after finishing the research project. Receipts from the Krueger National Park will be used for this purpose. And furthermore, only appropriate technologies will be used, which can be handled by local people. Within a socio-cultural study it will be worked out, how the local population can contribute to the operation of the water house.

GERMANY - HEIDELBERG:

Topic:

DEUS 21 - Decentralized Urban Infrastructure System

Partners:

Fraunhofer Institute Dr. Harald Hiessl

Institute of Urban Water Management, RWTH Aachen, Dr. Th. Buer

Level of knowledge:

In Germany centralized water supply and waste water treatment on a high technological standard predominate.

For some years alternative concepts on a smaller scale have been implemented at some locations (e.g. Luebeck, Freiburg).

Single components (bio-membrane reactor, nutrient recycling, ...) have to be optimized before they can be applied in new residential areas.

Main activities:

Implementation of an integrated decentralized concept of

water supply (drinking water quality)

waste water reuse

recycling of organic waste for energy recovery and recovery of nutrients (P, N)

cost-saving infrastructure (e.g. pipe-laying)

in a new residential area (about 600 residents).

Optimization of technologies, particularly waste water processing by bio-membrane technology

Modeling and sustainability assessment.

Comment on project funding:

The proposed combination of decentralized technologies meets several important aspects in protecting natural resources:

- Emissions into surface waters will be drastically reduced

- A significant reduction of drinking water consumption is expected by the use of rain water

- The need for energy and resources for fertilizer production can be reduced by the recycling of nutrients and closing of material cycles.

- This residential area will serve as a model for establishing and demonstrating a new standard of integrated alternative water management.

STATE OF THE ART ON MBR IN EUROPE

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ABSTRACT

In Membrane Bioreactors (MBRs) for wastewater treatment the secondary clarifier is replaced by a membrane filtration. This offers the advantages of a complete removal of solids as well as pathogenic germs at smaller footprint plants.

Meanwhile more than 30 plants in municipalities and more than 120 plants in industry are operated or under construction in Europe, most of them in Great Britain, Germany and Italy.

A severe disadvantage is the higher energy demand of MBRs which exceeds conventional activated sludge systems by a factor 2-3. This high energy consumption is mainly due to the coarse bubble aeration system installed directly underneath the membrane modules and operated to keep fouling under control. Investigations of the Oxygen Transfer Rate (OTR) and Standard Aeration Efficiency (SAE) in two existing full scale MBRs at different MLSS with both aeration systems respectively are reported. The SAE of the "crossflow" coarse bubble aeration system for fouling control is about three times lower than the fine bubble aeration system which provides oxygen supply. Thus for limitation of energy consumption the "crossflow" aeration should be optimised and be used only for fouling control.

KEYWORDS

Membrane bioreactors, realized MBRs in Europe, energy demand, oxygen transfer, sludge viscosity

INTRODUCTION

In industrial and municipal wastewater treatment membrane bioreactors (MBR) offer an alternative to conventional Activated Sludge Processes (ASP). Basically the membrane replaces the secondary clarifier. This overcomes the limitations to MLSS-concentrations of 3 to 5 kg MLSS/m³ of the conventional activated sludge process. Because the MLSS concentration is independent from sedimentation it can be increased significantly. MLSS values of up to 30 kg/m³ are reported. Most membrane bioreactors with submerged membranes are operated in the range of 10 to 15 kg/m³ MLSS. This means smaller foot print of the plants.

In addition, the effluent of the micro- or ultra filtration membranes with pore sizes of about 0.1 to 0.4 µm is free of suspended solids and basically free of pathogenic germs (viruses, bacteria, parasites), thus of higher quality compared to conventional effluent. As a matter of fact, the membrane not only replaces the secondary clarifier, but replaces treatment steps like sand filtration and UV-disinfection as well.

As a result, MBRs are of interest wherever high quality effluent is required, because of a sensitive receiving water body or quite often in combination with water reuse for irrigation or

as process water in industry. Anyhow, one disadvantage of MBRs is the often reported higher specific energy demand.

First a probably incomplete overview of MBRs in Europe with priority to Germany follows before some results concerning the energy demand are presented.

STATE OF THE ART

Beginning in the mid of the Nineties in Great Britain, meanwhile more than 30 municipal WWTPs and at least 120 "industrial" treatment plants in Europe are equipped with membrane bioreactors.

Municipal MBRs in Europe

Table 1 summarizes the municipal MBRs in succession of countries. As the list might be incompletely, it gives a fair overview.

Table 1: Municipal MBRs (3/03)

Country	MBR	Membrane	Flux m³/d *(P.E.)*	in operation since
United Kingdom	Greyabbey	Kubota	1,166	in 2003
	Skipsea	Kubota	1,300	in 2003
	Dittisham	Kubota	227	in 2003
	Lynmouth	Kubota	1,642	in 2003
	Kirubbin	Kubota	1,728	in 2003
	Longbridge	Kubota	1,555	in 2003
	Gardenstown	Kubota	692	2003
	Finstown	Kubota	278	2003
	Llangranog	Kubota	281	2003
	Lowestoft	Zenon	4,300	2002
	Moneyreagh	Kubota	580	2002
	Minehead	Kubota	260	2002
	Westbury	Kubota	4,700	2002
	Campbeltown	Zenon	6,500	2001
	Daldowie	Kubota	10,800	2001
	South Wraxall	Kubota	256	2001
	Swanage	Kubota	13,000	2000
	Porlock	Kubota	1,900	1998
	Kingston Seymour	Kubota	125	1995
Germany	Rödingen	Zenon	*(3,000)*	1999
	Markranstädt	Zenon	*(12,000)*	2000
	Knautnauendorf	Huber VRM	*(900)*	2002
	Schwägalp	Huber VRM	*(780)*	2003
	Monheim	Zenon	*(10,000)*	04/2003
	Waldmössingen	Zenon	*(2,600)*	in 2003
	Markkleeberg	Zenon	*(30,000)*	in 2003
	Nordkanal	Zenon	*(80,000)*	in 2003
France	Ile de Yeu	Zenon	2,260	
	Perthes en Gatinais	Zenon	900	
	Thelus	Zenon	183	
Spain	SPS S.A.	Zenon	400	
	Cepicma	Zenon	24	
	Cepicma Sun Granot	Zenon	23	
Italy	ASM Brescia	Zenon	38,000	2002
Netherland	Maasbommel, NL		480	

Belgium	Aquafin	Zenon	36	
Switzerland	Säntis	Zenon	40	

As can be seen the marked is dominated by two suppliers. Figure 1 shows the well known Kubota and Zenon systems. Two small plant in Germany are equipped with a quite new system called "Vacuum Rotation Membrane" (VRM), where 6 to 8 modules build up an element on a rotating disc (Figure 2).

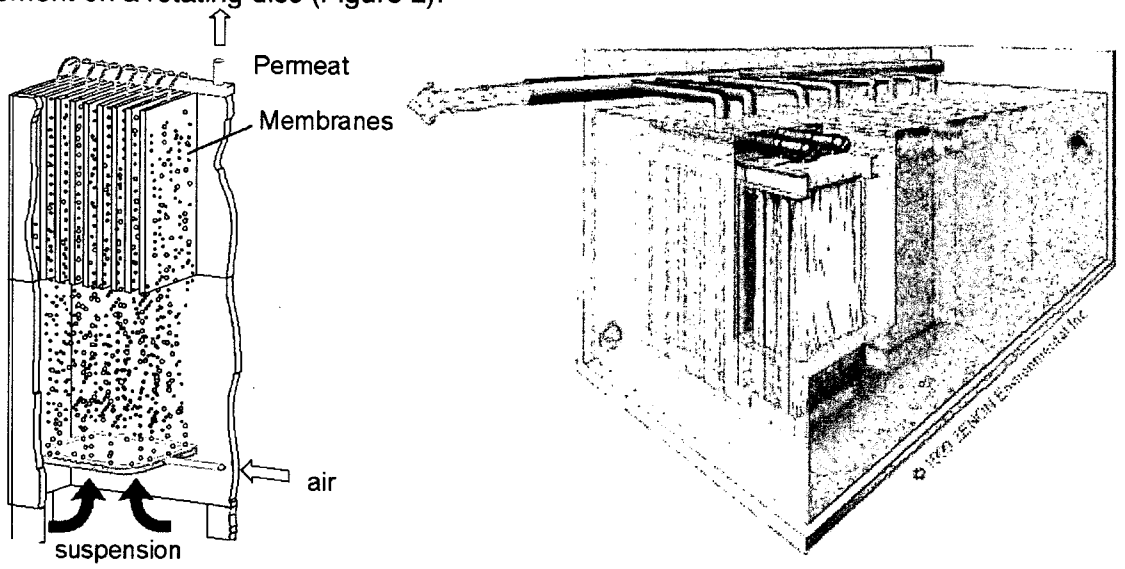

Figure 1: Kubota (l) and Zenon (r) membrane systems

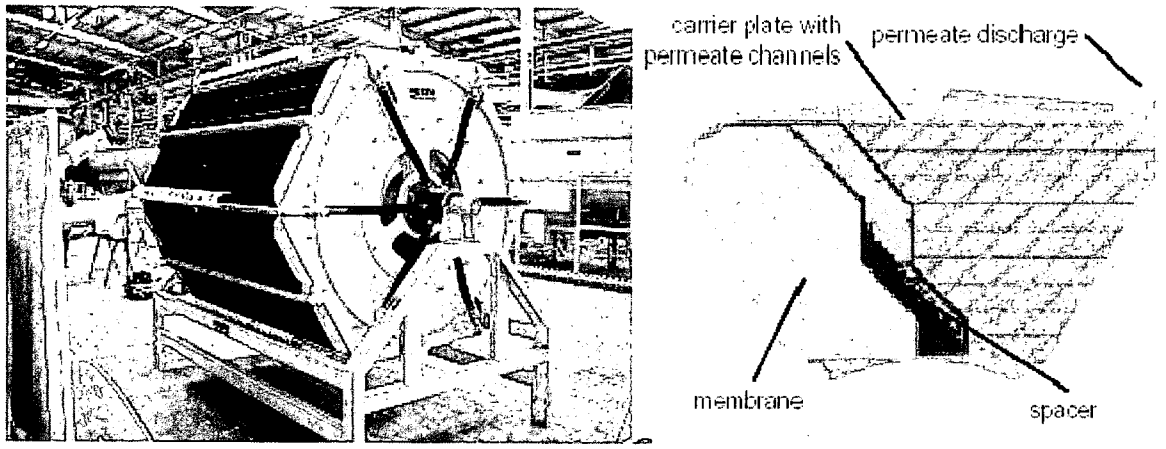

Figure 2: Huber Vacuum Rotating Membrane system (VRM system)

Industrial MBRs in Europe

A general survey of industrial plants is even more uncertain. A questionnaire dated in February 2002 resulted in the plants listed in table 2. Only plants with a throughput above 10 m^3/d are listed.

Table 2: Industrial MBRs in Europe

Industrial sector	numbers	Flux [m^3/d]
Automobile	1	225
Chemical Industry	15	70 – 1,360
Leachate	48	10 – 18,000
Food Industry	9	100 – 1,840
Tannery	5	40 - 800
Composting	2	40 – 50
Cosmetics	3	120 - 680
Malthouse	2	100
Paper	1	900
Pharmaceutical Ind.	15	50 – 1,500
Ships/ Cruisers	15	10 - 740
Tank cleaning	3	200
Textile Industry	5	10 –1,440
Rendering plants	4	40 - 960

COMMENTS AND EXPERIENCES

Pre treatment

The wastewater needs to be carefully pre treated before entering the MBR plant. It is advisable to remove abrasive or sharp edged materials which can hurt the membranes as well as fibers or hairs which can clog the membrane (modules) and lead to a dramatic and rapid decrease of the flux. Screens or even better sieves with mesh sizes < 0.5 mm have proved suitable. Further a grease trap should be installed, because oil and grease may influence the flux of the membranes negatively.

The hydraulic equalisation is of importance, because the membrane surface has to be designed according to the maximum inflow. Thus a storage and equalisation tank to cut the peaks is advisable.

Aeration Tank

Design and operation

The use of membranes to separate the biomass leads to some changes in the design and operation of the aeration tank. As already mentioned, the MLSS in MBRs can be raised to usually about 10 to 15 g/L. As the aeration tank is designed based on the load (F/M-ratio), higher MLSS and similar F/M as in conventional activated sludge plants, translates in smaller aeration tank volumes. Operational experience shows that MBRs can be simulated by the activated sludge model (ASM 1 and ASM3 by IWA). Thus in principal the biodegradation of organic compounds doesn't differ from conventional plants.

In principal two borderline cases of design and operation are possible:

- Small aeration tanks at the same F/M-ratio and similar surplus sludge production as in conventional ASPs

- Operation at extreme long sludge ages, i.e. very low F/M-ratio, minimizing the amount of surplus sludge but maximum of specific oxygen consumption thus high energy demands

There is no operation mode to get both positive effects, low energy consumption and zero sludge production rates.

Sludge characteristics and oxygen transfer

The sludge characteristic differs from conventional activated sludge, mainly due to the higher MLSS. The sludge viscosity increases with increasing MLSS. The viscosity of the MBR sludge is non-Newtonic i.e. it decreases at higher shear stress.
The higher viscosity may lead to a lower α-value (= ratio of the aeration coefficient k_La under process condition to the clean water transfer coefficient) which is about 0.6 at MLSS of 12 g/L compared to 0.8 at conventional ASP at MLSS of 3 to 5 g/L.

Energy Consumption

The specific energy demand of municipal membrane bioreactors is higher compared to conventional treatment plants. At the municipal MBR in Markranstädt (Germany) the energy consumption is reported to be about 1 kWh per m^3 inflow (Stein et al., 2001). Whereby the "crossflow" aeration is main energy consumer with about 0.7 kWh/m^3. In Rödingen (Germany) the membranes are installed in an external filtration tank, thus the energy demand is higher due to additional recirculation. The overall energy demand is reported to be about 2.0 kWh per m^3 inflow (Drensla, 2001) (mechanical treatment 0.6 kWh/m^3, biological station 0.35 kWh/m^3, filtration Unit 0.86 kWh/m^3, whereby the "crossflow" aeration consumes about 0.5 kWh/m^3, rest 0.2 kWh/m^3). Anyhow, it has to be considered that the plant was not optimised yet in respect of energy consumption.

Membrane Cleaning

The membranes require regular cleaning. It has to be distinguished between different cleaning procedures, as f. e.

- backwash with permeate
  (depending on the membrane/module type every few minutes)
- chemical enhanced backwash (e.g. daily)
- maintenance cleaning (e.g. weekly)
  e.g. NaOCl 13% - 500 ppm Cl, cleaning with water, Citric acid (0,5%) at pH 2.5 to 3, cleaning with water
- intensive cleaning (1-2 times per year) outside MBR
  e.g. with citric acid and NaOCl 1000 ppm at 35 °C

Frequency as well as type and concentration of chemicals depend strongly on wastewater composition, membrane and module type and are not standardized so far. In contrast, cleaning strategies are a focus of research with regard to avoid the use of chlorinated products (AOX-formation !) and to reduce the so called "aging" of membranes caused by the use of oxidizing chemicals.

Lifetime of Membranes

There are little reliable information about the lifetime of membranes. Although some are in operation since 5 to 6 years without failures respective with annual replacements of less than 3% [Churchhouse et al., 2003], others had to be replaced after 2 to 3 years because of serious fouling or even mechanical destruction. One can assume that lifetime is strongly correlated with the composition and pre treatment of the waste water, the applied cleaning strategies of the membrane modules, as well as with the type of membrane and module construction.

ENERGY CONSUMPTION

The specific energy demand of municipal membrane bioreactors (MBRs) is reported to be higher compared to conventional treatment plants.
The higher demand is due to additional energy consumers as the generation of the crossflow and as already mentioned a lower α-value. The α-values where reported in a wide range of 0.2 to 0.7 and discussed pretty controversial [Guender, 1999; Rosenberger et al., 2000; Cornel et al., 2002]. To quantify the α-values in full scale plants, oxygen transfer tests were performed in two municipal MBRs (Rödingen and Markranstädt, Germany). Further the oxygen transfer efficiency (OTE) and the standard aeration efficiency (SAE) were evaluated. In parallel to the oxygen transfer tests under process conditions, the viscosity of the sludge at different MLSS was determined.
Viscosity tests were performed using a rotating viscometer with a concentric cylinder measuring system. Thereby a rpm (revolutions per minute) is set and the system measures the shear stress and the viscosity in dependence of the angular velocity. In Figure 3 the viscosity at different shear stresses is shown.

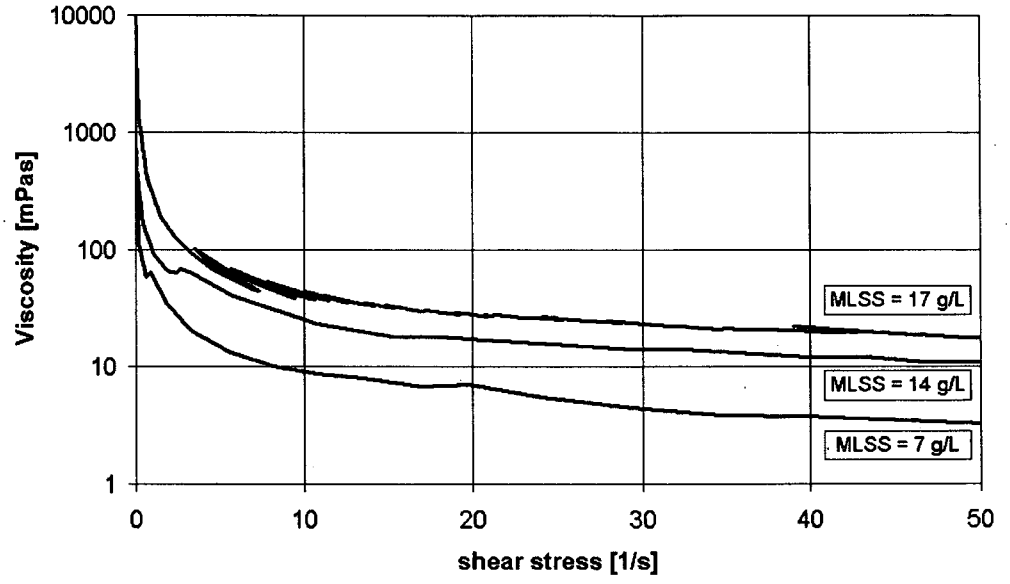

Figure 3: Viscosity vs. shear stress of MBR sludge at different MLSS concentrations

It can be seen that the viscosity decreases at increasing shear stress. Further the Figure shows an increasing viscosity at increasing MLSS concentration. Due to the non-Newtonic dynamic behaviour of the MBR sludge it is compulsory to give both shear stress and viscosity. Guender (1999) calculated from the bubble velocity a representative viscosity at a shear stress of 40 1/s.

The oxygen transfer tests in the two plants with fine bubble aeration system were performed with the absorption method. The oxygen transfer rate (OTR) [kg/h] is an absolute rate. A better comparable parameter is the oxygen transfer efficiency (OTE) [%/m]. The OTE in MBR#1 (Markranstädt) ranges from about 2.1 %/m to 4.3 %/m under process conditions at MLSS from 7 g/L to 17 g/L. Thus the oxygen transfer and therewith the OTE depends on the MLSS content. A similar result was obtained in MBR#2 (Rödingen). The OTE in clean water was estimated as 8.5 %/m, in mixed liquor the OTE decreased from 3.7 %/m to 2.8 %/m at increasing MLSS from 9.5 g/L to 14 g/L. At both municipal MBRs the OTE is in the same order of magnitude. In Figure 4 the OTE of both MBRs is depicted, including the standard deviations.

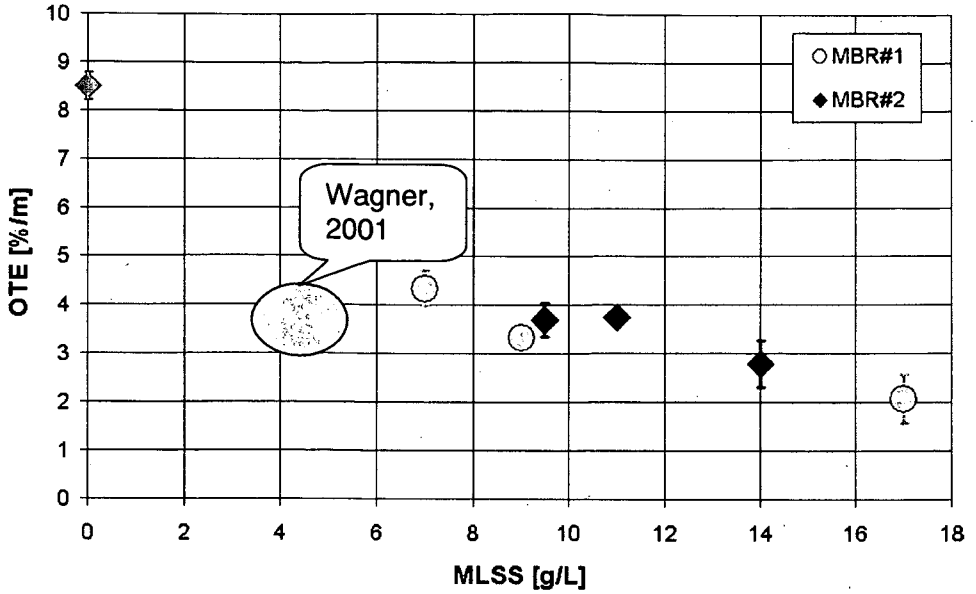

Figure 4: Oxygen transfer efficiencies of fine bubble aeration systems

Wagner [2001] analysed more than 300 treatment plants with respect to OTE-values. Compared to his results the measured OTEs correspond to a common fine bubble aeration system.

Oxygen transfer tests with the additional "crossflow" aeration system which acts as the source of scour at the membrane surface were performed. In order to generate a high liquid shear velocity the air flow rate from this aeration system is more than twice in value compared to the fine bubble aeration system. Figure 5 shows a comparison of the volumetric OTR of both aeration systems in the MBR Markranstädt.

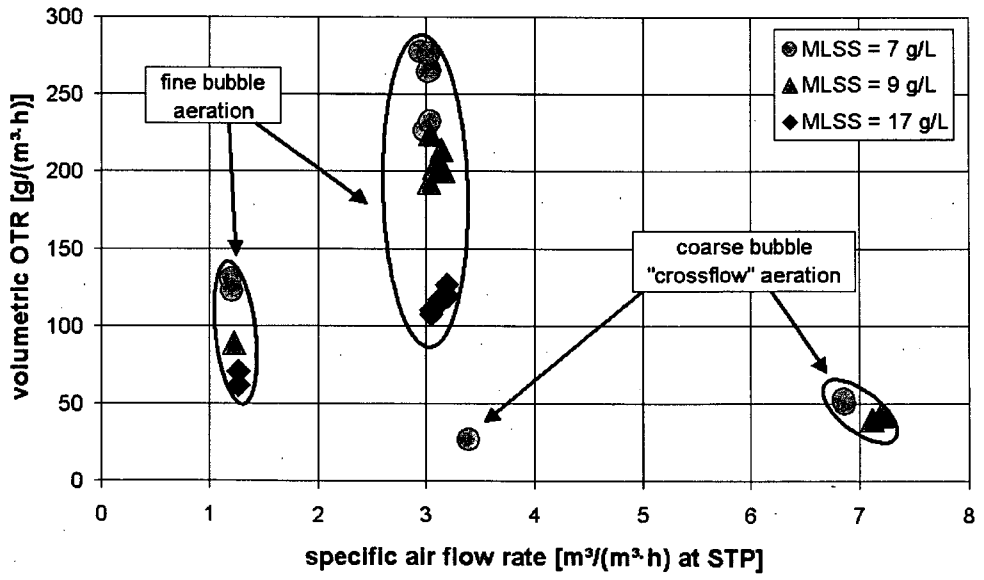

Figure 5: Comparison of volumetric OTR of both aeration systems (STP = standard temperature and pressure)

In evidence the OTR of the fine bubble aeration is much higher at less air flow. Otherwise, as positive side effect, the "crossflow" aeration is able to supply additional oxygen.

The specific aeration efficiency (SAE) indicates an energy consumption of the "crossflow" aeration of about three times the value of the fine bubble aeration (Figure 6). At MLSS of 7 kg/m³ an SAE of 0.8 kg/kWh for "crossflow" aeration was determined. For fine bubble aeration the SAE is about 2.4 kg/kWh at a specific air flow of 3 m³/(m³·h) at STP.

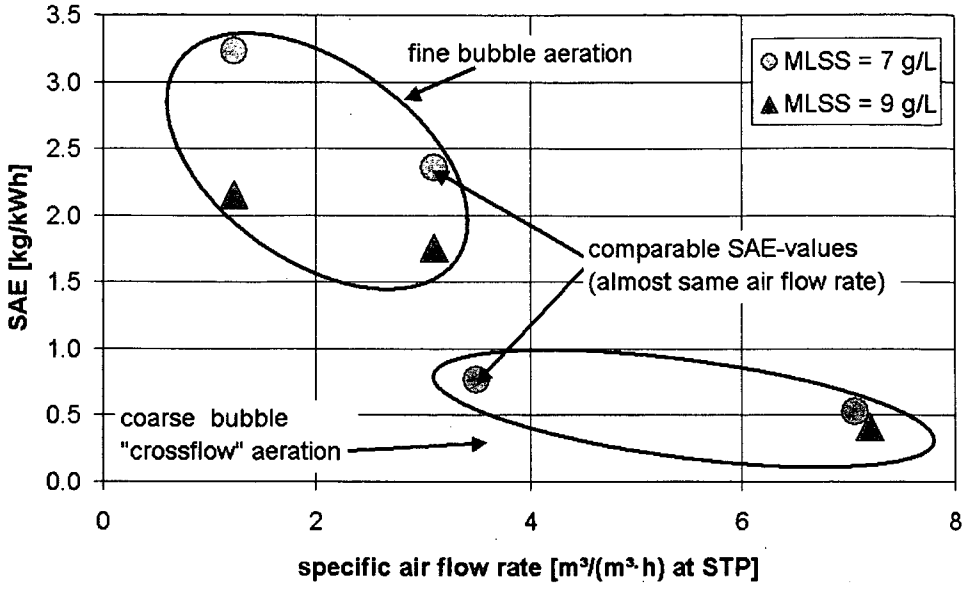

Figure 6: Aeration efficiency of both aeration systems

The α-value is defined as the ratio of the volumetric transfer coefficient under process condition (field k_La_{f20}) to the clean water transfer coefficient (k_La_{20}) according to following equation:

$$\alpha = \frac{k_La_{f20}}{k_La_{20}} \quad [-]$$

Due to this definition all influences regarding to the oxygen transfer are considered. For determination of the α-value it's compulsory to calculate the ratio at the same airflow rate and other conditions like depth of submergence.

Calculated mean α-values can only be depict in ranges. The ranges in Rödingen (MBR #2) result from the application of the off-gas method (variations in k_La and OTR in time). In Markranstädt (MBR #1) the ranges are larger because the clean water tests were performed under different hydraulic conditions compared to the tests under process conditions (absence of membranes in the clean water tests). Figure 7 depicts the average α-values in dependence of MLSS for the two full scale MBRs. Measurements between 7 and 17 kg/m³ MLSS concentration were performed. The average α-values in this range are between 0.7 and 0.4 respectively.

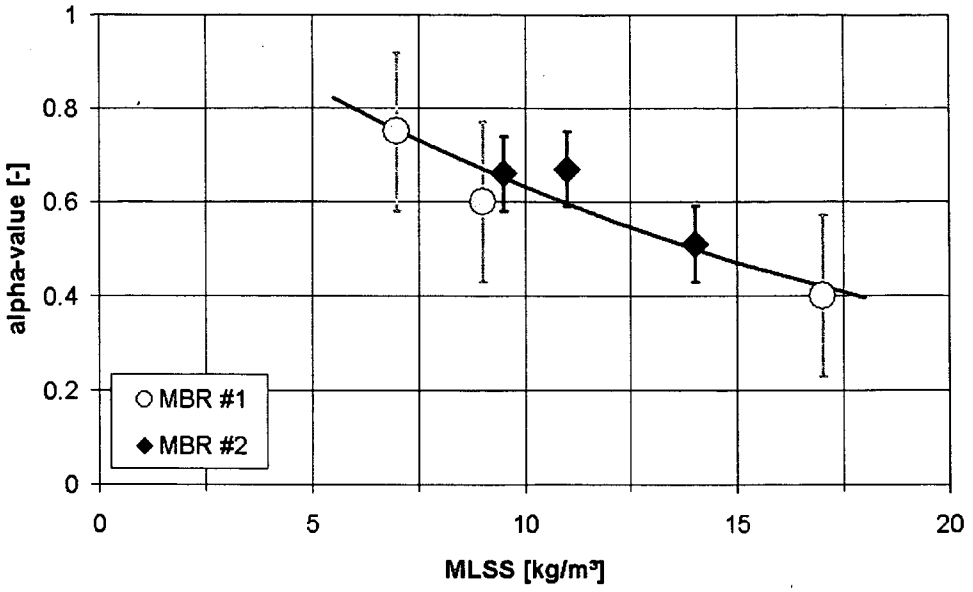

Figure 7: α-values in dependence of MLSS concentration for both municipal MBRs

Nevertheless a good correlation between α-value and MLSS concentration can be seen. Because of the measurements of the viscosity the α-values also can be depict in dependence of viscosity. In Figure 8 the average α-values vs. viscosity is shown.

According to Günder [1999] in Figure 8 the representative viscosity at shear stress of 40 1/s is used. It can be seen that the correlation between α-value and viscosity is in even better accordance as the correlation of α-value and MLSS concentration.

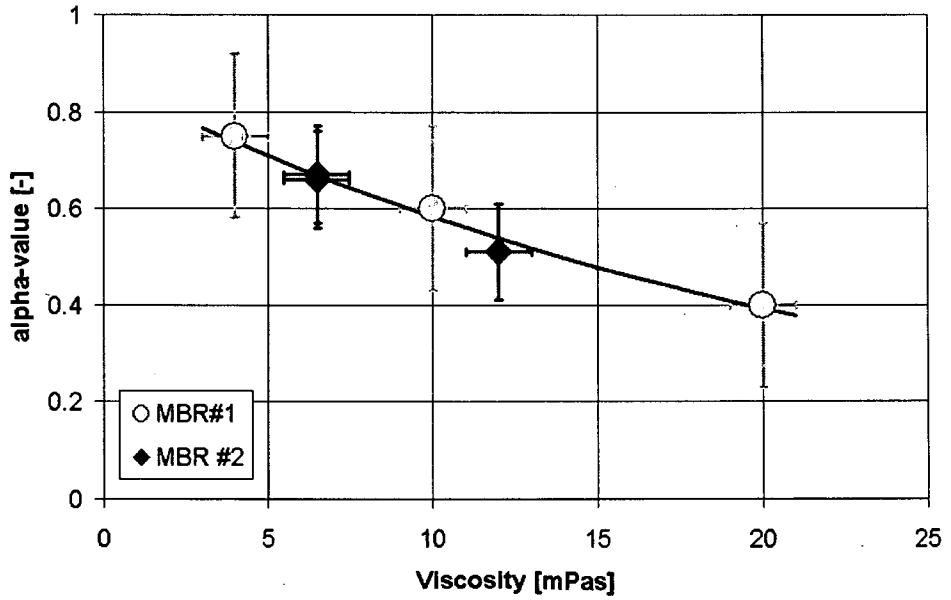

Figure 8: α-values vs. viscosity (at 40 1/s shear stress) for both municipal MBRs

CONCLUSIONS

About 30 municipal and more than 120 MBRs in industry are installed in Europe. Small footprints and high effluent quality free of suspended solids and basically free of pathogenic germs are the main objectives.

Disadvantageous is the higher energy consumption by a factor of 2 to 3 compared to conventional activated sludge plants. The overall energy demand of submerged systems is reported to be 1.0 to 1.5 (2.0) kWh per m^3 treated water. 2/3 of the energy in municipal MBRs is needed to generate the crossflow to control the fouling.

The α-value of fine bubble aeration systems in municipal full scale MBRs at 12 kg/m^3 MLSS is about 0.6 ($\pm$ 0.1), thus comparable to conventional municipal WWTPs at lower MLSS and lower sludge age but about 0.2 units lower as in conventional stabilization plants.

There are little information about the lifetime of membranes. Although some are in operation since 5 to 6 years almost without failures, others had to be replaced after 2 to 3 years because of serious fouling or mechanical destruction. One can assume that lifetime is strongly correlated with the composition and pre treatment of the waste water, the applied cleaning strategies of the membrane modules, as well as with the type of membrane and module construction.

Oxygen transfer tests of fine bubble aeration systems at different MLSS indicate a dependence of α-value and MLSS. At decreasing MLSS increasing α-values are observed. This might be caused by the higher viscosity of the MBR sludge.

The standard aeration efficiency (SAE) of the "crossflow" aeration system for fouling control is about three times lower than the fine bubble aeration system which provides oxygen supply. Thus for limitation of energy consumption the "crossflow" aeration should be used for fouling control only.

The measured results regarding the α-value show that MBRs represent an alternative solution to conventional WWTPs in wastewater treatment. The energy consumption for oxygen supply in municipal MBRs is due to the measurements in full scale MBRs in the same order of magnitude as municipal conventional WWTPs. However the energy for the generation of the crossflow (for fouling control) is for the total energy consumption of higher importance.

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CHARECTERISTICS OF MBR IN MUNICIPAL WASTEWATER TREATMENT

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ABSTRACT

The application of MBR to municipal wastewater treatment has recently begun and it is expected that the application of MBR will increase from now on. The authors investigated several subjects related to MBR. These were influence of organic substances on the filterability of MBR activated sludge, reduction of excess sludge production by MBR and reuse of MBR effluent. The research results are introduced in this paper.

KEYWORDS

MBR, organic substances, filterability, reduction of sludge excess sludge, reuse, Coliphage

1.INTRODUCTION

The MBR has been applied in many fields such as for industrial or on-site wastewater treatment, and there are many such plants in use. However, MBR has not yet been used for municipal wastewater treatment in Japan, because it has not been cost effective as the amount of wastewater to be treated is usually more than that of on-site or industrial wastewater treatment. Nevertheless, the recent decline in the cost of membranes has made it realistic to use MBR for municipal wastewater treatment.

Japan Sewage Works Agency (JSWA) has been conducting a series of studies over several years on using MBR for municipal wastewater treatment, and the results were summarized in "Technical evaluation of MBR" at the end of last year to promote the use of MBR. As a result, five local municipalities have already decided to use MBR and plant design work is now proceeding. The first MBR plant for municipal wastewater treatment in Japan will start operation in 2004, and the application of MBR for municipal wastewater is expected to increase.

This paper outlines the results of several of the studies conducted by JSWA on application of MBR to municipal wastewater.

2. INFLUENCE OF ORGANIC SUBSTANCES ON THE FILTERABILITY OF MBR ACTIVATED SLUDGE

2-1. BACKGROUND OF THE STUDY

Since MBR uses membrane filtration for liquid-solid separation, the condition of activated sludge is sometimes thought to be unimportant. However, the sludge characteristics significantly affect the performance of MBR, as poor filterability will cause membrane fouling and a rapid rise of trans membrane pressure (TMP), which will require frequent chemical washing of the membrane. It is essential to determine the filterability of activated sludge and the factors that affect the filterability for the optimum operation of MBR, and therefore a practical operational index for the filterability of MBR activated sludge is necessary.

This study investigated the influence of organic substances on the filterability of the activated sludge of MBR.

2-2. MATERIALS AND METHODS

A pilot-scale MBR plant with a reactor volume of 4 m^3 was used for the study. The reactor was composed of an anoxic tank and an aerobic tank, with the mixed liquor circulated from the aerobic to the anoxic tank. The plant was located in the experiment yard of JSWA's R&D Department in Toda city. The plant treated 4.1 m^3/d of actual municipal wastewater supplied from the adjacent large-scale WTP which uses a combined system. The flow scheme of the MBR pilot plant used for the study is shown in Figure 1.

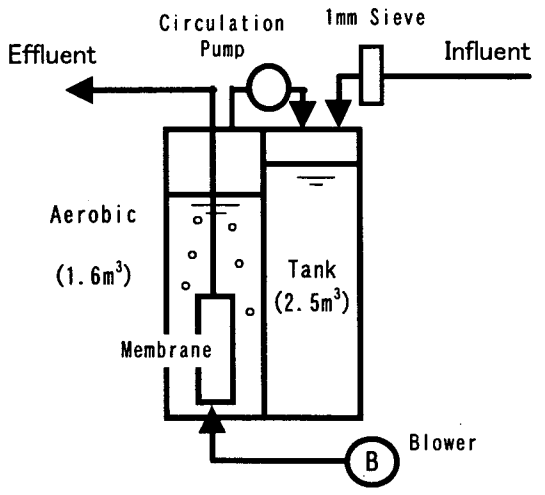

Table 1 Specification of membrane

Material	Polyolefine
Membrane Type	Flat Plate MF
Panel size	490mm × 1000mm × 6mm
Pore size	0.4 μm
Design Permeate Flux	0.4$m^3/m^2/d$

Figure 1 Pilot plant flow scheme

The dimensions of the MBR were L170 cm, W116 cm, H230 cm and the reactor consisted of an anoxic tank (2.5 m^3) and an aerobic tank (1.6 m^3). The MF membrane unit consisted of seven FP (flat-plate) membrane elements each having a membrane surface area of 0.8 m^2.

Three membrane units were submerged in the aerobic tank. The total membrane surface area was 16.8 m^2. The specifications of the membrane are shown in Table 1. The permeate flux was 0.26 $m^3/m^2/d$.

The primary effluent of the large-scale WTP was fed as influent to the MBR, after pre-treatment by a 1-mm mesh metal sieve in order to prevent damage to the membranes by debris. The MBR was operated with intermittent feeding, i.e. three days with continuous feeding followed by four days with no feeding per week. The feeding rate was 4.1 m^3/d and the membrane permeate flux was maintained at 0.26 $m^3/m^2/d$. The HRT during the feeding period was 24 hours. Aeration as well as circulation from the aerobic tank to the anoxic tank were continued during the no-feeding period. The inflow rate corresponded to 1.74 m^3/d for the whole period on average. The circulation rate was 300% of inflow volume. The BOD-SS load was 0.004 kgBOD/kgMLSS on average.

Chemical washing of the membrane was scheduled to be performed when TMP reached 23 kPa, by injecting 0.5% of NaOCl into the membrane elements from the effluent line. Aeration for oxygen supply and for continuous washing of membrane surfaces required 10–20 L/min of air volume for each membrane element.

An automatic sampler that took 24-hour composite samples was used to take the influent samples. For the effluent, grab samples were used since no significant fluctuations in water quality were observed. The sampling and water quality measurement were done on Monday, Wednesday and Friday every week. Regarding the measurement of dissolved TOC (DOC) of the mixed liquor, MLSS was centrifuged at 3,000 rpm, and then the filtrate that passed through a 1-μm GF/B filter was measured by a Shimadzu TOC analyzer.
Dehydrogenase activity was measured according to the "Wastewater analysis methods". [1] Polysaccharides were measured by the anthrone-sulfuric acid reaction method. Proteins were measured by the Lowry method.

2-3. RESULTS AND DISCUSSIONS

1) Paper filter test as an index of sludge filterability

The paper filter test is often used on site to evaluate the filterability of MBR activated sludge. The paper filter test simply filters 50 ml of activated sludge by a 5C paper filter, and the filterability of MBR activated sludge is judged from the volume filtered in 5 minutes. Usually, if the volume filtered in 5 minutes exceeds 5 ml, the filterability of the sludge is judged to be good. Since the test can be completed quickly using simple tools, the test is suitable for on-site use.

It has been empirically shown that the results of the paper filter test roughly correspond to the filterability of activated sludge. For example, the filtrate volume of the paper filter test depends on

water temperature and when water temperature drops, the filtrate volume decreases because of the viscosity of water increases. However, the paper filter test using warmed activated sludge in winter showed that the filtrate volume was not equal to the level at the corresponding water temperature as shown in Figure 2. Therefore, it is clear that the characteristics of activated sludge play an important role, in addition to water temperature, for sludge filterability.

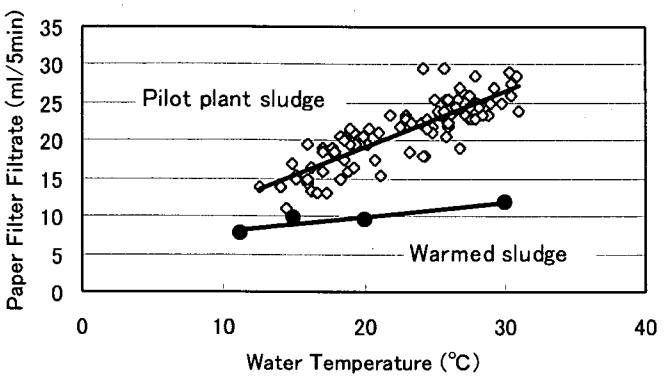

Figure 2 Water temperature and paper filter test result

2) DOC

Figure 3 shows the relationship between DOC of the reactor mixed liquor and water temperature. As shown in the figure, DOC depended on water temperature and tended to increase as water temperature fell. This indicates that more organic substances remain in the reactor mixed liquor when the water temperature is low.

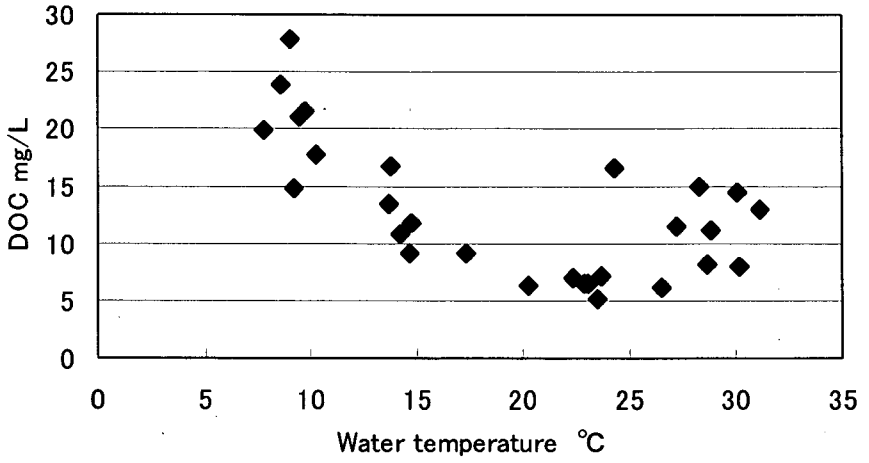

Figure 3 DOC and water temperature in the reactor

Figure 4 shows the filtrate volume of the paper filter test and DOC. The filtrate volume of the paper filter test was clearly related with DOC of the reactor mixed liquor, and decreased as the

DOC concentration of reactor mixed liquor increased.

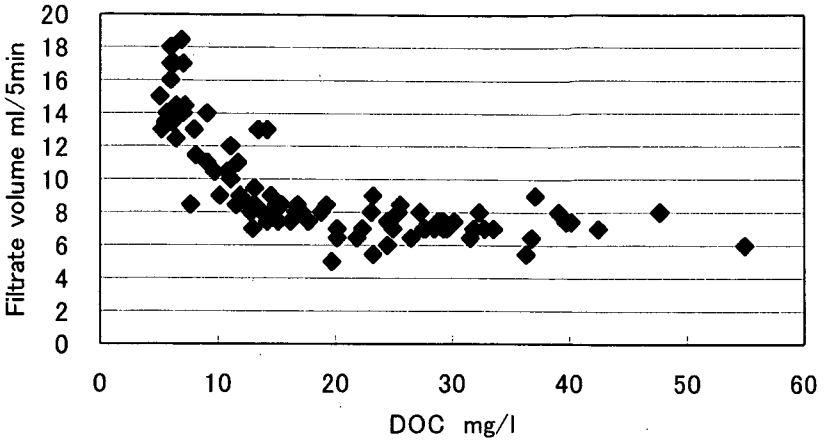

Figure 4 Filtrate volume of the paper filter test and DOC

It is considered that DOC of the mixed liquor represents organic substances including extra-cellular polymeric substances (ESP) that are not captured in the sludge. As shown in the figure, lower DOC resulted in better filterability.

3) Dehydrogenase activity

Dehydrogenase activity (Dt) consists of a substrate-dependent segment (Ds) and endogenous-respiration-dependent segment (De). De was measured with activated sludge that had been rinsed with tap water. Since the measurements showed that De accounted for the major portion of Dt, the influence of organic substances was evaluated based on De.

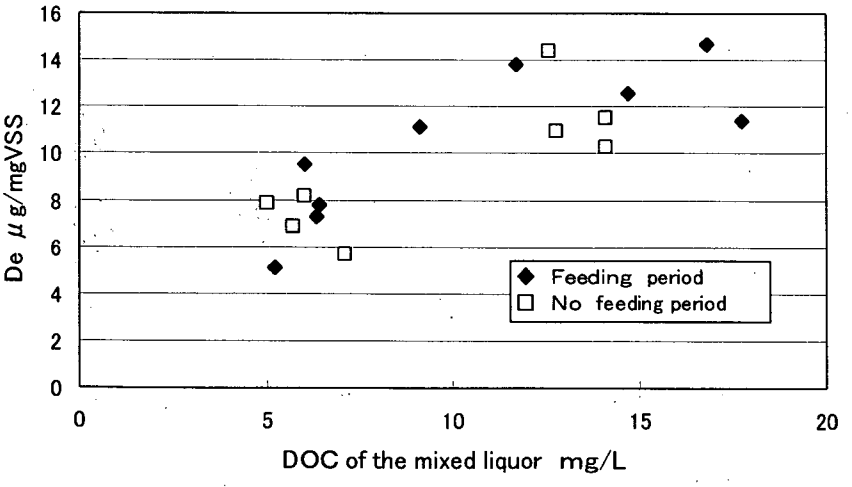

Figure 5 DOC and De

Figure 5 shows the relationship between DOC and De. Figure 6 shows water temperature and De.

As shown in Figures 5 and 6, De depends on DOC of reactor mixed liquor and water temperature. This indicates that the decline in biological activity at low water temperature led to organic substances remaining in the activated sludge, which were represented by DOC.

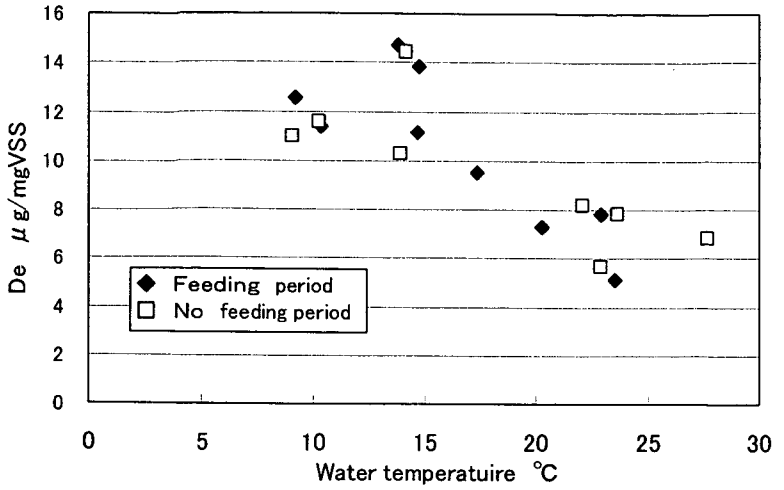

Figure 6 Water temperature and De

4) Polysaccharides and proteins

The behavior of polysaccharides and proteins in the reactor mixed liquor was investigated. Figures 7 and 8 show the change of proteins and polysaccharides concentration respectively. Protein concentration decreased in the reactor mixed liquor compared with that in the inflow and 4 mg/l of protein was detected in the effluent. On the contrary, polysaccharides concentration increased in the reactor compared with that in the inflow, and was below the detectable level in the effluent.

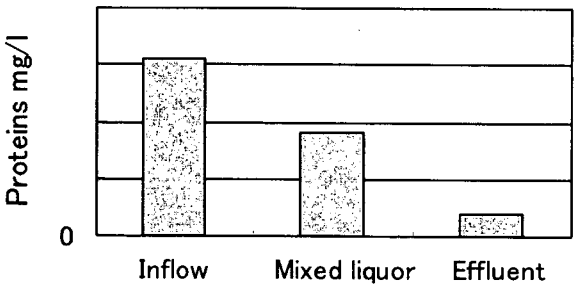

Figure 7 Change of proteins

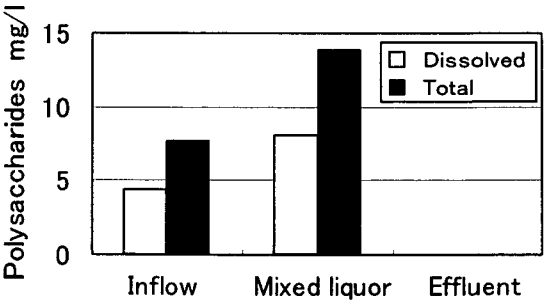

Figure 8 Change of polysaccharides

It has been pointed out that EPS is a major cause of membrane fouling and thus degrades filterability. [2] EPS is the product of metabolic activity of activated sludge microorganisms and consists of polysaccharides and proteins. The reason why polysaccharides increase in the reactor is considered to be that EPS is produced in the reactor and mostly rejected by the

membrane, thus increasing the polysaccharides concentration in the reactor on the assumption that polysaccharides are the main component of EPS.

Figures 9 and 10 show the influence of reactor water temperature on protein concentration and on polysaccharides concentration in the reactor mixed liquor.

Protein concentration in the reactor mixed liquor showed no clear relationship with water temperature but polysaccharides concentration in the reactor mixed liquor showed a much closer correlation, increasing as water temperature dropped.

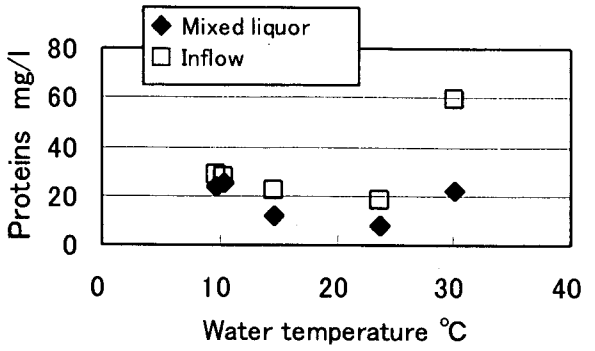

Figure 9 Proteins and water temperature

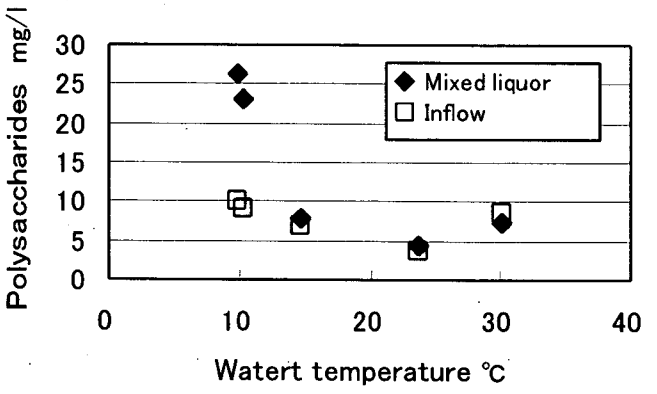

Figure 10 Polysaccharides and water temperature

Figures 11 and 12 show the relationship between DOC and proteins as well as DOC and polysaccharides respectively. The DOC in the reactor was closely related with polysaccharides as shown in Figure 12, but was not closely related with proteins as shown in Figure 11. This indicates that polysaccharides such as included in EPS was the main component of organic substances and could be represented by the DOC in the mixed liquor.

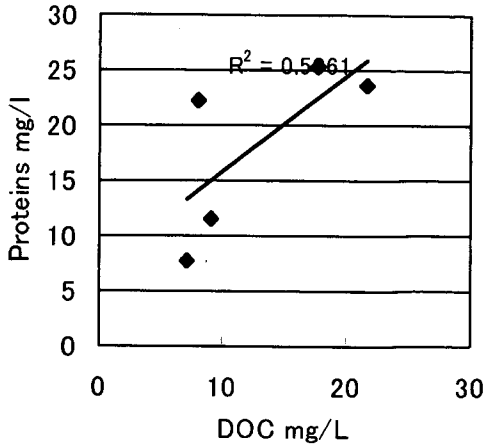

Figure 11 DOC and proteins

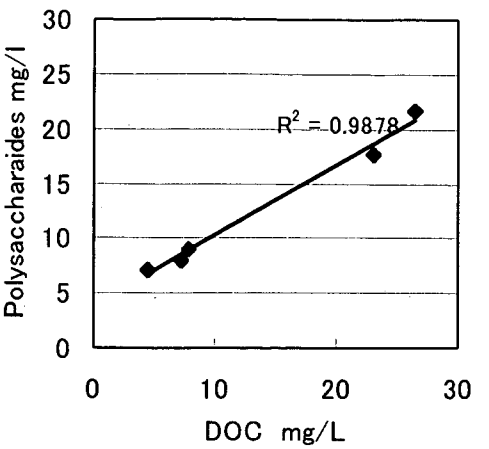

Figure 12 DOC and polysaccharides

5) Index of filterability

From these results, it is considered that DOC in the reactor mixed liquor represents the remaining quantity of organic substances, consisting mainly of polysaccharides. DOC depends on water temperature, suggesting that more organic substances remain in the mixed liquor of the reactor at low water temperature. As already shown in Figure 4, when DOC concentration became high, the filtrate of the paper filter test decreased. These results imply that the filterability declines at low water temperature because larger quantities of organic substances remain in the mixed liquor than at high water temperature.

2-4. CONCLUSIONS

The following conclusions were obtained in the study:

1) The remaining organic substances, mainly polysaccharides, affect sludge filterability and the behavior of such remaining substances can be expressed well by DOC in the mixed liquor.
2) The paper filter test roughly describes the filterability of sludge as an index for daily operation of MBR. However, since the test cannot describe the influence of each factor, periodical DOC measurements should also be performed to correctly determine the filterability.

3. SLUDGE REDUCTION BY INTERMITTENT FEED MBR

3-1. BACKGROUND OF THE STUDY

The treatment and disposal of sludge are serious issues of wastewater management. To reduce the cost of sludge disposal, various processes for reducing sludge production have been developed or proposed recently. Most of these methods are based on the principle that the excess sludge is solubilized either by physicochemical or biological methods, and the solubilized excess sludge is then returned to the reactor to be biologically decomposed. As sludge solubilization methods, ozone oxidation, acid or alkaline treatment, electrolysis and biological method such as the use of thermophilic bacteria for instance are applied. These processes are able to reduce the volume of generated sludge, and almost eliminate it in some cases. However, increased solubilization rate of sludge degrades the effluent quality by increasing the COD level and decreasing the transparency. A wastewater treatment method with less sludge production and yet that does not adversely affect the treated water quality is required.

To meet these two conflicting requirements, the authors focused on the membrane bioreactor (MBR) process. The MBR process can be operated with increased SRT and thus reduces sludge production, which is one of the major advantages of the process. Another significant feature of the MBR process is the high quality of effluent. The MBR process can maintain high MLSS level in the reactor because the process has no gravitational solid-liquid separation. As a result, the MBR process assures operation at a long SRT leading to the reduction of excess sludge production in spite of rather short HRT. The operation of MBR is usually conducted at SRT of about 20 days. However, at longer SRT, further reduction of excess sludge can be expected. The authors studied intermittent feed operation of MBR, which assures long SRT, and consequently sludge reduction by aerobic digestion effects by a pilot plant scale experiment for about one year.

3-2. MATERIALS AND METHODS

This study was conducted at the same time as the above-mentioned study using the same pilot plant.

3-3. RESULTS AND DISCUSSIONS

1) Sludge production

The results of measurement of both influent and effluent are shown in Table 2. Figure 13 shows the course of reactor MLSS and reactor water temperature. The MLSS concentration was about 5,500 mg/l at the beginning and increased to about 8,000 mg/l after 100 days of operation. It then reached 7,000 mg/l at the end of the experiment period after gradual

decrease and increase. It is considered that the weak inflow due to storm water was the cause for the temporary decrease of MLSS.

Table 2 Influent and effluent quality

	Influent			Effluent		
	Min	Max	Average	Min	Max	Average
pH	7.4	7.9	7.5	7.2	7.8	7.5
BOD	28.1	98.6	65.1	0.2	1.2	0.5
S-BOD	8.6	43.7	23.1	–	–	–
COD	25.1	77.6	56.6	3.8	6.0	5.0
S-COD	10.9	42.3	23.9	–	–	–
TOC	12.8	99.8	50.5	2.3	5.3	3.5
S-TOC	8.5	27.4	17.2	–	–	–
SS	35	128	75	0	0	0
T-N	15.5	36.5	28.1	4.3	22.2	10.2
T-P	1.7	5.1	3.9	1.7	4.2	2.5

Unit is mg/l except pH
S-BOD, S-COD and S-TOC were for filtered sample by 1 μ m GFB filter.

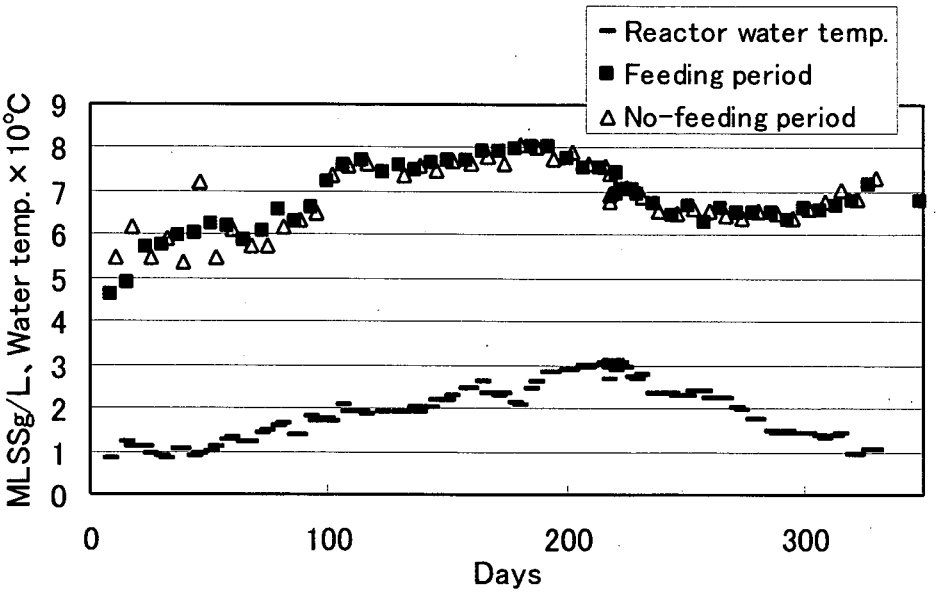

Figure 13 Reactor MLSS and water temperature

The organic content of MLSS, which was initially 82%, decreased to 74% by the 250th day and then slightly increased to 78%, remaining at a stable level thereafter.

During the experimental operation no excess sludge was extracted. If the increase of MLSS and sludge taken for measurement are regarded as excess sludge production, the sludge production rate for the first 100days during which MLSS continued to increase before reaching the stable condition was calculated to be 0.6 gSS/gSSremoved. This value

corresponded with that obtained in our former experiment that used only aerobic tank of the same pilot plant and operated it without sludge extraction for 140days. [3] On the other hand, the sludge production rate for the whole experiment period was calculated to be 0.21gSS/gSSremoved or 0.25gSS/gBOD_5removed.

If increased MLSS during the period and sludge taken for measurement are regarded as excess sludge which should have been extracted, the estimated SRT of the experiment operation based on the mean MLSS, 6,900 mg/l, can be calculated to be about 1,000 days. Figure 14 shows the sludge production rate and SRT obtained in several MBR pilot plants treating municipal wastewater. The sludge production rate depends on the SRT of the process. In Japan, MBR is usually operated at SRT of about 20days and therefore the sludge production rate is estimated to be about 0.65gSS/gSSremoved. However, as shown in Figure 14, smaller sludge production rate was obtained under prolonged SRT condition. Davies et al. reported 0.26 gSS/gBOD_5rem of sludge production rate with a 15.5m3 pilot operated at 45days of SRT. [4] These results suggest that small sludge production rate can be expected in MBR when operated at prolonged SRT longer than 30days.

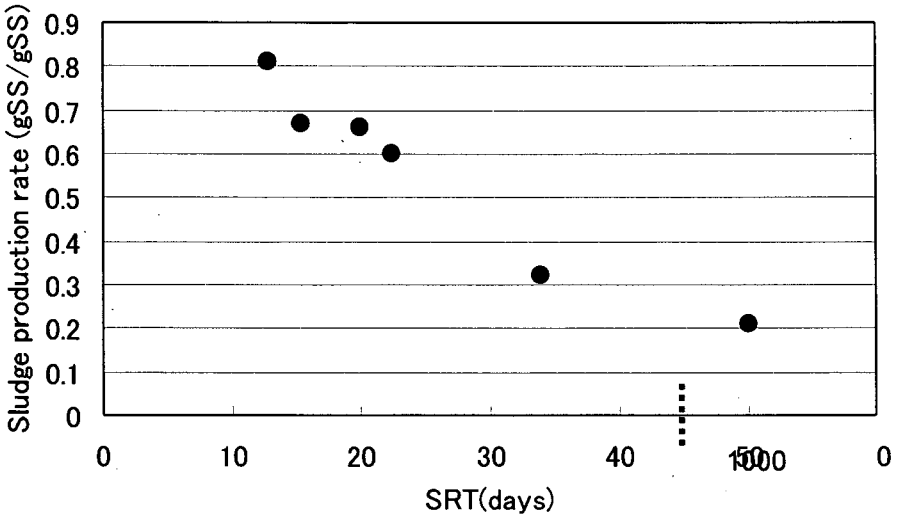

Figure 14 SRT and sludge production rate of MBR

Table 3 shows the sludge production rate used for the design of various suspended growth biological treatment processes in Japan for comparison. It is expected that MBR process produces less excess sludge than other processes at 20days SRT and it can be much smaller under prolonged SRT condition.

Table 3. Design sludge production rate of various processes

Process	Sludge production rate*
CAS	1.00
SBR(High load)	1.00
SBR (Low load)	0.75
Oxidation ditch	0.75
Extended aeration	0.75

*gSS/gSSremoved

2) Membrane fouling

Membrane fouling is the most serious trouble in the operation of MBR. It is pointed out that the production EPS by activated sludge microorganisms is the main cause of membrane fouling. [2] Hamaya et al. reported that pulse high loading feed after a no-feeding period in the intermittent operation because such feed may induce the production of EPS that causes membrane fouling accelerated rapid membrane fouling. [5]

In the experiment, intermittent feeding was continued for about one year, but no rapid membrane fouling was observed and the pilot plant could be operated without chemical washing. Figure 15 shows the course of TMP and permeate flux during the experiment period. TMP showed moderate change and remained below the critical level, i.e.23kPa, at which chemical membrane washing is required.

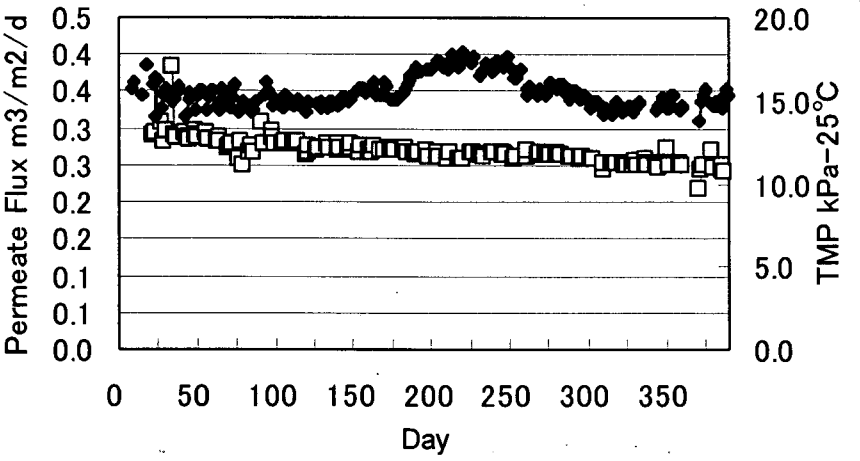

Figure 15 TMP and permeate flux

Figure 16 shows the cumulative concentration of DOC of the reactor mixed liquor during the feeding and no-feeding period respectively. As shown, DOC concentrations were lower during the no-feeding period than in the feeding period. Judging from the result, the reason that filtration could be continued for a long time without membrane fouling is considered that organic substances including EPS were efficiently degraded during the no-feeding period thanks to the very low organic loading condition (0.004gBOD /gMLSS/d).

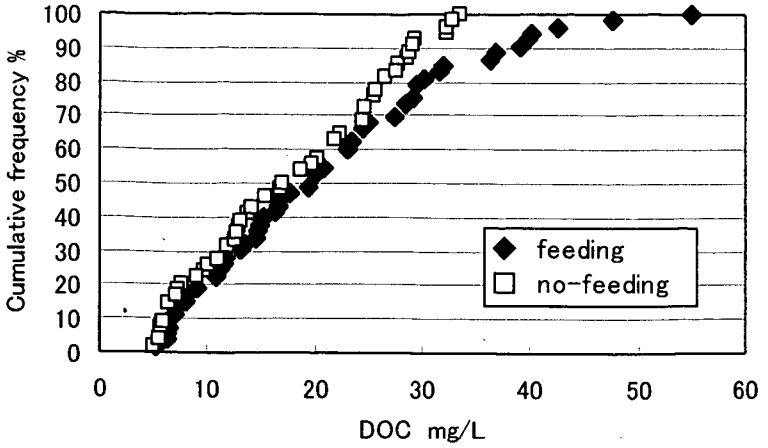

Figure 16 Cumulative frequency of DOC

3-4. Conclusions

The conclusions obtained in this study were as follows:

1) An intermittent feed MBR with low loading was operated for about one year and no excess sludge extraction was necessary during the period.
2) The calculated sludge production rate based on the increase of MLSS for the whole period was 0.21gSS/gSSremoved or 0.25gSS/gBODremoved.
3) The plant showed stable operation and no serious membrane fouling because of the intermittent feed was observed.
4) It is considered that MBR with intermittent feed can reduce excess sludge production and thus can reduce costs for sludge treatment and disposal. In practice, intermittent feed operation of MBR under continuous inflow condition will be enabled by means of preparing several reactor tanks and feeding wastewater into each tank in turn.

4. REUSE OF MBR EFFLUENT

4-1. Background of the study

As emphasized in the 3rd World Water Forum, there will be a shortage of fresh water in many areas worldwide, particularly in Africa and Asia. Fresh water will be an extremely valuable resource in the 21st century, so the reuse of treated wastewater should be further promoted to save fresh water.

One of the advantages of MBR is the excellent quality of its effluent including high removal of bacteria, which is suitable for a wide range of reuse purposes. But any risks inherent in its reuse need to be clearly identified. The authors evaluated the characteristics of MBR effluent for reuse purpose and investigated the removal of Coliphage as an alternative index for viruses. In addition to that, removal of several important endocrine disrupters by MBR was also investigated.

4-2. Materials and methods

For the study, a pilot-scale plant in the JSWA experiment center in Mohka city was used. Figure 17 shows the flow scheme of the plant. The pilot plant treated 25 m^3/d of actual municipal wastewater with an HRT of 6 hours. The reactor consists of an anoxic tank and an aerobic tank, with mixed liquor circulated from the aerobic tank to the anoxic tank. A flat plate-type MF membrane unit with a pore size of 0.4 μm was immersed in the aerobic tank and operated at a permeate flux of 0.63 $m^3/m^2/d$. Raw wastewater from the Mohka wastewater treatment plant, which is a medium-sized WTP employing the CAS process, was supplied to the MBR after removing coarse materials with a 1-mm metal sieve.

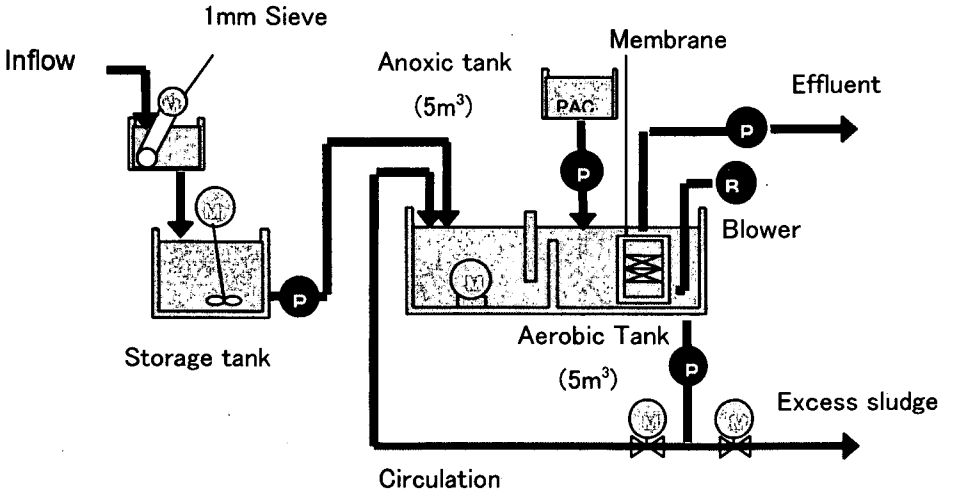

Figure 17 Flow scheme of the pilot plant

Coliform group numbers were measured by the MPN method. *E. coli* K-12F+ was used as the Coliphage host train. Coliphage was measured by the plaque forming method. Endocrine disrupters except 17β estradiol were measured by GC-MS, while 17β estradiol was measured by the ELISA method.

4-3. Results and discussions

1) Characteristics of MBR effluent in view of reuse

Table 4 shows the Japanese guidelines on recycled wastewater for landscaping and recreational use respectively. The MBR effluent was measured twice concerning the items related to purpose of reuse. The results are shown in Table 5. As shown, the MBR effluent satisfied the standards of the guideline except the value of chromaticity for recreational use. The chromaticity of MBR effluent, which was measured twice, was 14 and 20, which were somewhat higher than the required value of 10 for recreational use.

Table 4 The Japanese guidelines on recycled wastewater

	Landscape use	Recreational use
Coliform group	≦1,000CFU/100ml	≦50CFU/100ml
BOD_5	≦10mg/l	≦3mg/l
pH	5.8–8.6	5.8–8.6
Turbidity	≦10	≦5
Odor	Not offensive	Not offensive
Chromaticity	≦40	≦10

Table 5 The results of the measurement

No	Items	Primary inflow	CAS effluent (after chlorination)	MBR effluent
1	BOD_5 (mg/l)	99.7	1.5	<0.5
	TOC (mg/l)	98.7	4.5	3.8
	Chromaticity (degree)	150	20	20
	Odor (–)	septic odor	odorless	soil like odor
2	BOD_5 (mg/l)	207	1.5	0.5
	TOC (mg/l)	73	3.4	2.6
	Chromaticity (degree)	200	20	14
	Odor (–)	septic odor	aromatic odor	odorless

Regarding the remaining color of the MBR effluent, a yellowish-brown color was noticeable. The color originated mainly in urobilin and stercobilin, which are contained in human excreta and are not easily biologically degraded. Ozone or activated carbon treatment would be required for further removal of color from the MBR effluent.

2) Removal of *E. coli* and bacteriophage

As expected, *E. coli* was not detected in the MBR effluent, whereas several hundred were detected in the effluent of the CAS plant treating the same municipal wastewater as shown in Table 6. Coliphage was removed by MBR at an efficiency of 5 log.

Figure 18 shows the change of Coliphage count in inflow and Figure 19 shows those in MBR and CAS plant effluents in 24 hours. MBR showed steady and high removal of Coliphage, which were not detected during the measurement period, whereas Coliphage were present in the CAS effluent.

Table 6 Removal of Coliphage

	Primary Effluent			Effluent		
	mean	max.	min.	mean	max.	min.
CAS	3.6×10^5	1.1×10^6	1.5×10^5	2.7×10^2	4.9×10^2	40
MBR	3.6×10^5	4.9×10^5	1.2×10^5	1	5	0

(PFU/100ml)

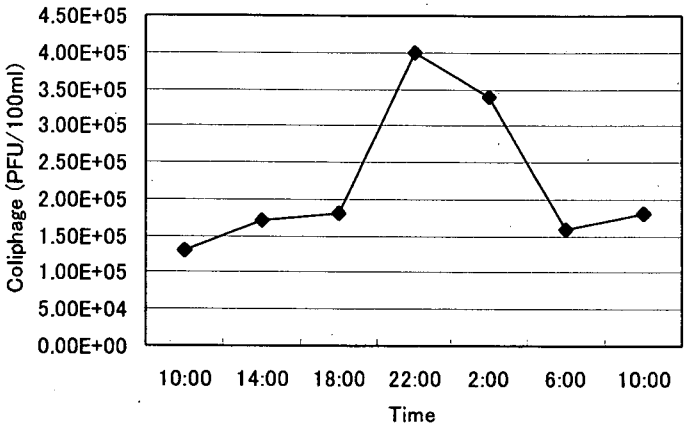

Figure 18 The change of Coliphage in inflow

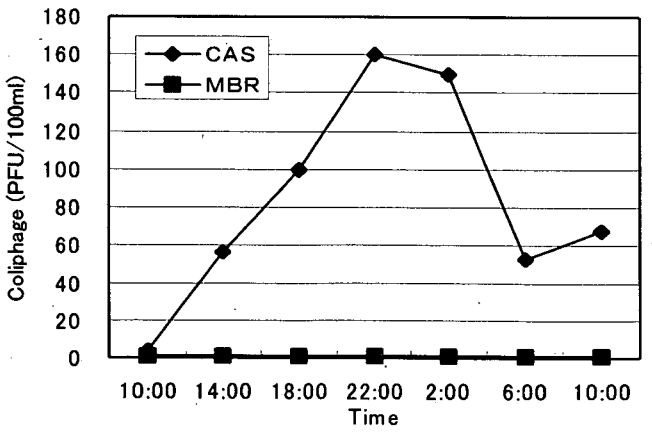

Figure 19 The change of Coliphage in effluent

Table 7 shows the Japanese guideline for viruses for treated wastewater for various purposes of reuse according to the infection risk. This requirement of virus removal is based on final effluent. Since a CAS plant can usually achieve a virus removal efficiency of 3 log, the virus removal efficiency of MBR corresponds about 2 log after final effluent. This value meets the requirement of virus removal efficiency for recreational use for dipping hands and feet at an infection risk of 10^{-2}. These results show that MBR effluent satisfies at least the recommended removal efficiency of viruses for miscellaneous uses such as sprinkling in the Japanese guideline.

Table 7 Required virus removal efficiency for various reuse purposes

Reuse purpose	Target annual infection risk		
	10^{-2}	10^{-3}	10^{-4}
Recreational (dipping the whole body)	2.5	3.8	5.0
Recreational (dipping hands and feet)	1.3	2.3	3.3
Fall and fountain (large scale)	1.5	2.6	3.7
Fishing pond	1.1	2.1	3.1
Sprinkling water for lawn	0.84	1.8	2.8
Flush water for toilet	–	0.43	1.5

(log)

3) Mechanism of Coliphage removal

Although Coliphages are far smaller than the pore size of the MF membrane employed, they were efficiently removed by MF filtration. It has been reported that membrane filtration without activated sludge showed poor removal of Coliphage. [6] It has also been reported that the removal efficiency of Coliphage was affected by the degree of membrane fouling, and that membranes after several weeks of operation showed better removal of Coliphage than new membranes. [7] Therefore, a possible explanation for Coliphage removal by MF membrane is that Coliphages become attached to flocks of activated sludge or are captured in the gel layer that forms on the surface of the membrane.

In this study, the measurement of Coliphage, both in the activated sludge and in the supernatant, showed that 99% of Coliphage were present in the activated sludge, indicating that they attach themselves to the activated sludge. [8] Thus, the mechanism of bacteriophage removal appears to be that Coliphage are held in the activated sludge, attach to the activated sludge flocks, and thus are rejected by the membrane together with the flocks.

However, the Coliphage removal mechanism needs to be investigated further in order to judge whether the MBR stably and efficiently removes viruses.

4) Removal of endocrine disrupters

Several important endocrine disrupters, such as nonylphenol, bisphenol A, DEHP, benzophenone and 17β estradiol in the MBR effluent were measured. The results were compared with the data obtained in the previous nationwide survey on the behavior of endocrine disrupters in many municipal wastewater treatment plants, most of which were CAS plants.

As shown in Table 8, the comparison showed that the endocrine disrupter concentrations in MBR effluent were almost the same as those in the effluents of existing CAS plants, except that the level of benzophenone in the MBR effluent was slightly lower than that in the CAS effluent.

Table 8 Endocrine disrupters in effluent

Substance	MBR	National survey
Nonylphenol	0.1	tr (0.2)
	0.1	
Bisphenol A	0.02	tr (0.02)
	0.03	
DEHP	<0.2	tr (0.4)
	<0.2	
Benzophenone	0.01	0.05
	0.01	
17β estradiol	n.d.	n.d.
	n.d.	

note: The upper row data was measured 19th Sep. 2002
The lower row was data was measured 25th Sep. 2002

4-4. Conclusions

The following conclusions were obtained in this study:

1) MBR effluent has characteristics that make it suitable for wastewater reuse, but a slight yellowish-brown color remained in the effluent. Further treatment, such as by ozone or activated carbon, will be required to remove this color.
2) MBR showed good removal of Coliphage. The removal mechanism appears to be that Coliphages are held in the activated sludge and thus rejected by the membrane together with activated sludge flocks.
3) No significant differences were observed between MBR and CAS in the removal of main endocrine disrupters.

5. PERSPECTIVES ON THE DEVELOPMENT OF MBR IN JAPAN

The application of MBR to municipal wastewater treatment has just begun in Japan and the first MBR plant for municipal wastewater will start operation in FY 2004, with another ten plants beginning operation in the next few years. These are mostly small-scale plants, but the MBR is expected to find various applications such as for renewal, retrofitting and upgrading of existing WTPs. The recent fall in cost of membranes and utility fees will also promote the application of MBR to larger facilities.

6. ACKNOWLEDGEMENTS

The Ministry of Land, Infrastructure and Transport supported this research. The data in Figure 14 were obtained in a joint study carried out from 1998 to 2001 together with Kubota Corporation, Mitsubishi Rayon Engineering Co., Ltd., Hitachi Plant Engineering & Construction Co., Ltd. and Nishihara Environment Technology Inc. The research on the reuse of MBR effluent was conducted jointly with Hitachi Plant Engineering & Construction Co., Ltd.

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RECOVERY OF PHOSPHATES IN MUNICIPAL WASTE WATER TREATMENT PLANTS

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INTRODUCTION

The aim of waste water treatment is to clean the waste water to such an extent that it reaches a given quality. Due to the principle of mass conservation, withdrawal of pollutants from waste water, such as heavy metals and organic halogen compounds, as well as elimination of useful material like minerals and nutrients are linked with it.

The major part of the material withdrawn from the waste water during treatment is found in the sewage sludge (in Germany about 2.5 – 3.0 million tons of dry matter per year [1], [2]), that in Germany is still used in agriculture in big amounts. The main interest of this type of reutilisation is to use the nutrients contained in the sludge for fertilisation.

Even after accentuation of standards for indirect discharger during the last decades, from which resulted lower pollutant content in municipal sewage sludge, we can start from the assumption that not all sludge constituents which are toxic for men and/or the environment have already been discovered. During reutilisation of the sludge in agriculture, these substances would be released into the environment and, with this, be an incalculable risk. At present about 1 to 1.4 million tons dry matter per year [1], [2] are recycled in agriculture. In the course of sustainable agriculture, in Germany efforts to eliminate the pollutant potential from sewage sludge by incineration becomes more and more important, compared to the amount of recycled material.
However, complete abdication from sludge reutilisation in agriculture would have for result that the phosphate compounds transferred into the sewage sludge during waste water treatment would no longer be available for plant fertilisation, and thus would have to be substituted by mineral fertilisers. With view to the phosphate deposits with low impurities (particularly in respect of cadmium) being already considerably exhausted (and non-renewable), this represents a conflict for the purposes of sustainable handling of scarce natural resources.

Therefore it has to be examined to what extent it is possible to recycle valuable compounds of the sewage sludge already during waste water treatment and before its disposal.

NUTRIENT CONTENTS AND USABLE POTENTIALS IN WASTE WATER AND SEWAGE SLUDGE

Utilisation of phosphates contained in waste water and sludge is possible just if the nutrient content allows economic and ecologically feasible recovery. On principle the following potentials are available:

In Germany the specific phosphorus load in waste water is about 1.6 – 2.0 g per inhabitant and day [3]. Related to the population connected to sewage treatment plants, the annual amount from municipal waste water is then about 50,000 tons P. Additionally about 20,000 tons P/a from indirect industrial discharges reach the waste water treatment plants. Considering the phosphorus effluent standards for municipal waste water treatment plants (1 mg P/L for plants > 100.000 PT), this corresponds to a quantity of about 64,000 tons of phosphorus per year which can be recovered during the waste water treatment process.

Concerning recovery, the usable potentials from the aqueous and the sludge phases can be differentiated as follows:
Starting from an average phosphorus content in the raw waste water of approx. 1.8 g per inhabitant and day, i.e. 9 mg/L at an average waste water quantity of 200 L per inhabitant and day, about 0.6 g per inhabitant and day or 1/3 of the phosphorus influent load are extracted from the waste water flow together with the sludge by sedimentation and/or incorporation, thus without targeted measures.

In case the legally binding value is fully used, the resulting potential for recovery from the aqueous phase will then be at least 33 % up to maximal 67 % of the average phosphorus influent load.
Without using increased biological phosphorus elimination or a precipitation process it is possible to recover from the sludge about 22 – 33 % of the phosphorus influent load. Using the last-named procedures this part can be increased up to approx. 90 %, related to the influent, so that finally the complete usable phosphorus influent load in the sludge phase will be available for recovery.

In Germany the phosphate quantity recoverable in the field of waste water corresponds to approx. 145,000 tons P_2O_5. With this quantity it would be possible to substitute about 40 % of the phosphate fertiliser sales of the year 2000/2001 (about 350,000 tons P_2O_5). This corresponds to 17 % of the P_2O_5 quantity necessary in the whole Federal Republic of Germany, related to the P_2O_5 demand of agricultural soils/ crops and in accordance with competent fertilising practice – as stated by the Federal Environmental Office [5].

STATE OF RECOVERY OF PHOSPHATES IN WASTE WATER AND SLUDGE TREATMENT

Several years ago far-reaching removal of phosphates from waste water has been realised at all big waste water treatment plants in Germany, in order to avoid excessive nutrient immission into water bodies. For this purpose simultaneous precipitation with metal salts in the activated sludge stage is mainly used. Due to the circumstances described above, it becomes actually more and more important to prepare the ground for phosphorus recovery instead of phosphorus removal. Here especially the experiences from European countries as well as from Japan are used as basis for considerations which take into account the circumstances in Germany. A few pilot plants as well as a couple of plants within the framework of research projects are already run.

In the following both well-known and rather new technologies with different approaches for the recovery of phosphates on wwtp's are described. This list is not exhaustive.

THE PHOSTRIP PROCESS

The Phostrip process (Figure 1) [9] is a biological-chemical process for the recovery of phosphates from the secondary sludge of municipal waste water treatment plants. Premise for increased phosphorus uptake of the activated sludge is that anaerobic and aerobic zones are flown through. The Phostrip process is able to meet the legally binding value of 1 mg P/L without using iron or aluminium salts [10].

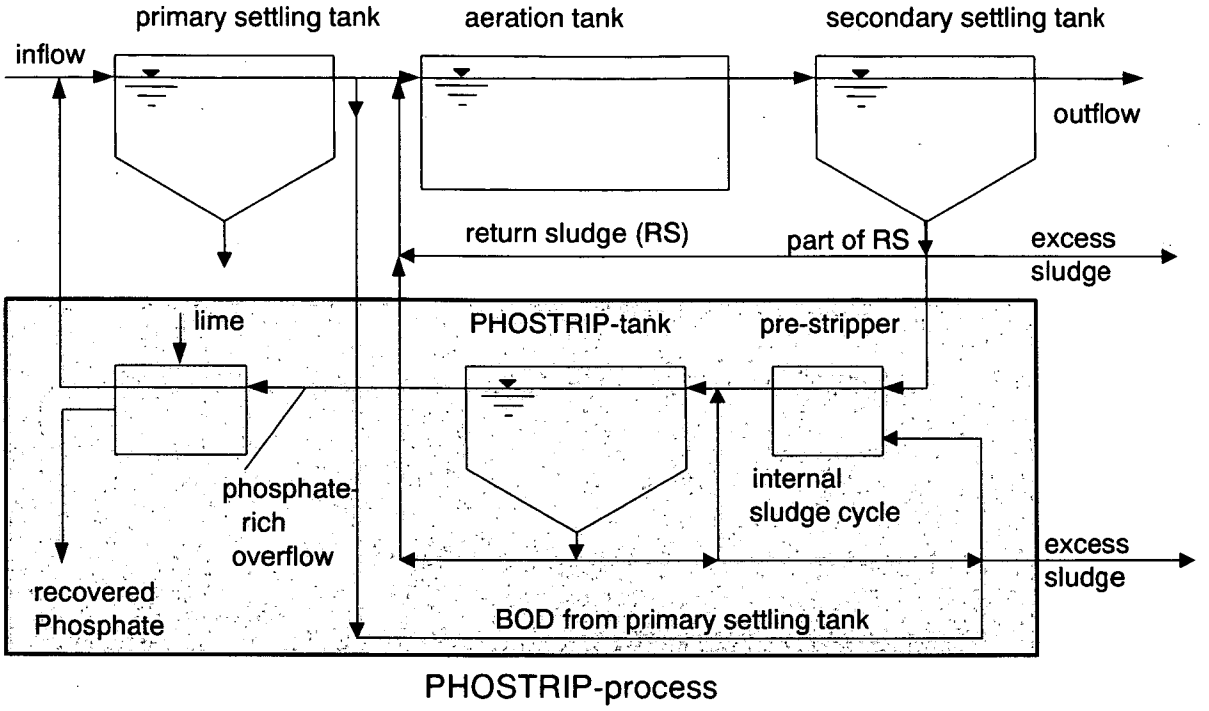

Figure 1: Flow sheet of the Phostrip process [9], modified

A split-stream of the secondary sludge is piped together with part of the pre-cleaned waste water into the pre-stripper, where the nitrate still present in the sludge water is denitrified and where organic acids develop which accelerate dissolution of phosphate in the succeeding Phostrip tank. In the Phostrip tank the micro-organisms emit the stored phosphate reserves again by their cell metabolism. The sludge, now poor in phosphates, settles under anaerobic conditions and is partly fed back into the aeration tank, where it accumulates phosphate again. The overflow of the Phostrip tank, which is rich in phosphate is fed to the precipitation reactor.

The phosphates released in the water phase of the settled sludge in the Phostrip tank are kept back by the internal sludge cycle and thus get into the clear water part of the stripper. Therewith it is avoided that too much dissolved phosphate is fed back into the biological stage of the waste water treatment plant. In the precipitation reactor, phosphate precipitates by the use of lime milk at pH values of more than 8.5 as calcium phosphate and then is separated. The precipitation product contains about 33 % up to 41 % P_2O_5 in the dry mass and is free of interfering substances [9]. So the precipitation product meets the demands for raw material of the Thermphos process for phosphate production [6]. It is also possible to use sodium aluminate instead of calcium; in this case, however, the utilisation of the product is strongly limited [4]. Since the supernatant liquor of the precipitation is fed back into the influent of the waste water treatment plant, no limit values have to be observed, i.e. it is not necessary to carry out phosphate precipitation to a residual concentration below 1 mg P/L. If

necessary, a sludge separator can be used which separates the precipitated phosphate from the liquor. [4], [9], [10], [11]
About 45 % of the phosphorus can be recovered at best. Various operational problems had for result that both plants at Darmstadt (Germany) had to be closed down, so that in Germany there is no Phostrip plant in operation by now [4]. Some plants in the USA and in Austria are still working.

CRYSTALLISATION PROCESSES

Crystallisation processes for phosphorus recovery can easily be integrated into the processes in municipal waste water treatment. They can be divided into main-stream and split-stream processes. In both variations phosphate precipitates using chemicals, e.g. calcium, and is recovered that way; the pH has to be set at approx. 9. Using calcium hydroxide, iron or aluminium salts are saved, that normally are used for chemical phosphorus elimination.

Crystallisation processes have been tested in the Netherlands (e.g. Westerbork, Heemstede), England, Japan and Australia and put in operation in Geestmerambacht (Netherlands) in 1994 for 230.000 PT [8], [13].
Especially the mainstream crystallisation (Figure 6) can easily be integrated in existing municipal waste water treatment plants. After biological waste water treatment phosphate elimination is done by adding $Ca(OH)_2$ in a crystallisation unit. Under favourable conditions it is possible to recover about 70 % of the phosphorus load contained in the influent of the waste water treatment plant. It has to be taken into account that the crystalliser operated in the mainstream has to be designed for all hydraulic peaks.

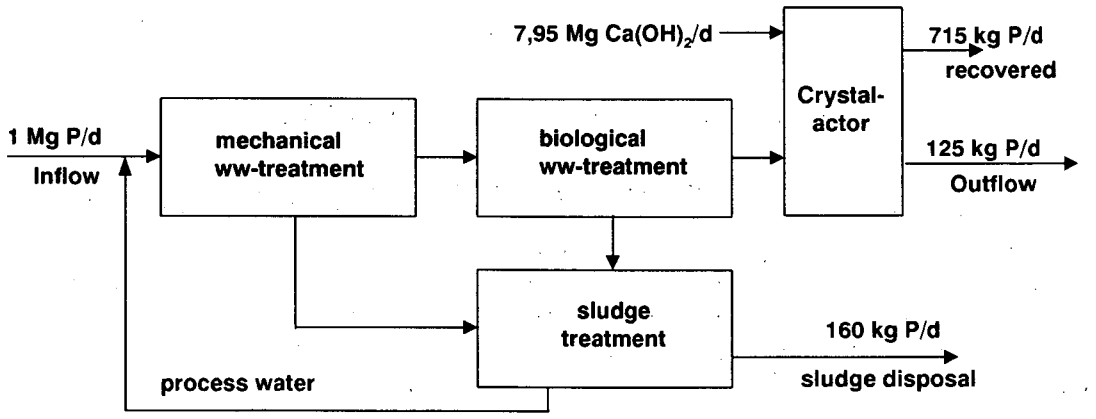

Figure 2: Flow sheet of the mainstream crystallisation

In split-stream crystallisation, used in combination with increased biological phosphorus elimination (Figure 3), part of the sludge rich in phosphorus from the biological process is treated in a settling tank and a suceeding crystaliser. Studies carried out in Geestmerambacht have shown that under local conditions up to 65 % of the phosphorus load in the plant influent could be recovered. Based upon usual German approaches, this value seems to be very high.

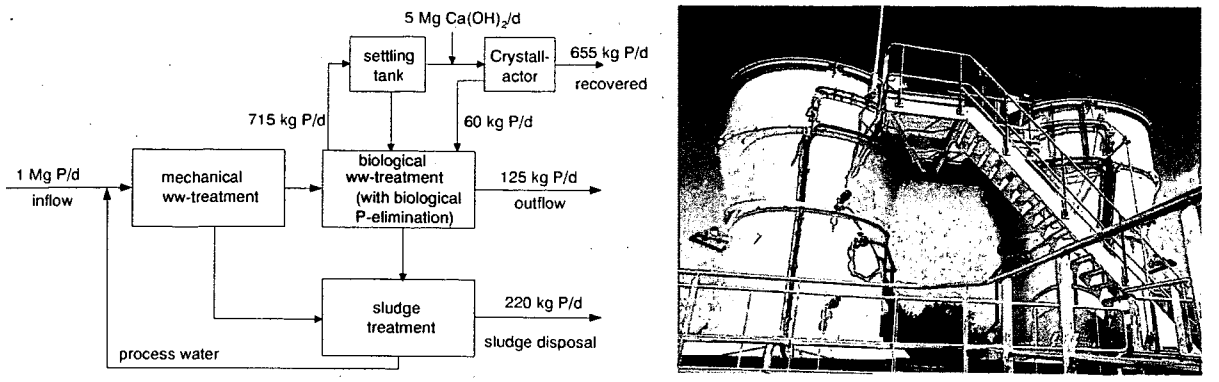

Figure 3: Flow sheet of a Bio-P plant with split-stream crystallisation and view of the crystalliser

As a consequence of the crystallisation processes there is the risk that the operation of the wwtp is soon disturbed by the formation of incrustations in aggregates and pipes. Moreover, after crystallisation the pH value has possibly to be adjusted to discharge conditions by adding acids (e.g. carbonic acid).

There are several possibilities in process engineering to implement crystallisation [16]:

- DHV crystalliser,
- RIM-NUT,
- Unitika PHOSNIX,
- Kurita fixed bed,
- CSIR fluidised-bed reactor.

The nutrients recovered by means of the crystallisation process as calciumphosphate, magnesium-ammonia-phosphate (MAP, only in the split-stream) or hydroxylapatite (HAP) can be used directly for fertilising in agriculture or after processing in the phosphate industry.

PRISA-PROCESS, CONSIDERING THE EXISTING WASTE WATER TREATMENT TECHNOLOGY

Within the scope of several research and development projects carried out at present at the Institute of Environmental Engineering of RWTH Aachen University (ISA), processes are studied which allow simple phosphate recycling based on the process technology installed, but increased biological phosphorus removal presumed. A process being tested in the field of anaerobic sludge and process water treatment is described more precisely in the following.

The first step of the PRISA process is increased acidification of the raw sludge (Bio P) with phosphate dissolution in a dissolution reactor (e.g. pre-thickener) (Figure 4). Then the raw sludge is separated from the supernatant which contains the major part of the phosphate which had been biologically bound before as well as a smaller part of dissolved phosphate from the hydrolysis of biomass. Thus it is possible to concentrate more than 40 % of the phosphorus load from the raw waste water in this split-stream. It is particularly important to gain the phosphorus before the sludge digestion, where parts of dissolved phosphates are fixed again to sludge particles.

Sludge digestion follows, where increased incrustrations of tanks, aggregates and pipes are no longer expected, as a result of preceding phosphate separation. Now the sludge is dewatered again. The centrate produced is rich in ammonia and finally will be mixed with the process water from pre-thickening. By adding magnesium oxide, phosphate as well as ammonia finally precipitates as struvite in the precipitation reactor:

$$Mg^{2+} + NH_4^+ + PO_4^{3-} \rightarrow MgNH_4PO_4 \cdot 6\,H_2O$$

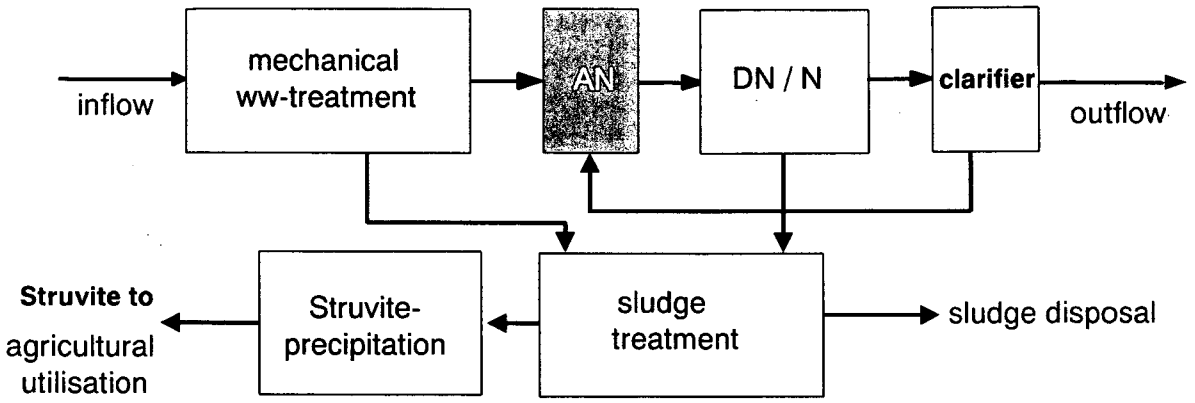

Figure 4: Acidification of the raw sludge and phosphate precipitation from the split-stream-flows as Struvite

As positive side effect, the nitrogen content in the centrate of approx. 0.45 kg N/kg P is reduced, which is linked with phosphate precipitation. Pilot-scale experiments in this connection are being carried out at the test plant of ISA.

The MAP crystals recovered can easily be dewatered and might be used in a decentralised way in agriculture [17], [12] or in the production of fertilisers.
The MAP process intended for nutrient recycling had already been studied in the 1980s at ISA. At that time, however, with the aim to remove ammonia nitrogen from the process water. Several pilot plants had been installed and operated at different places in Germany. At the end all the plants were closed down because at that time there was seen neither the necessity for nutrient recovery, nor an economical way of operation. The CAFR process (chemical ammonia precipitation with recycling, Figure 5) represents a follow-up development of the MAP "one-way" precipitation. In the CAFR process ammonia is stripped by means of steam from the precipitated MAP by alkalisation (MgO) at temperatures of about 70 °C, so that magnesium phosphate (MP) can be used again for MAP precipitation.

The crude ammonia liquor can be used for flue gas denitrogenation or serve as nitrogen source in fertiliser production. Recycling is five to eight times possible, afterwards secondary constituents, enclosed in the magnesium phosphate, concentrate and disturb the process [20].

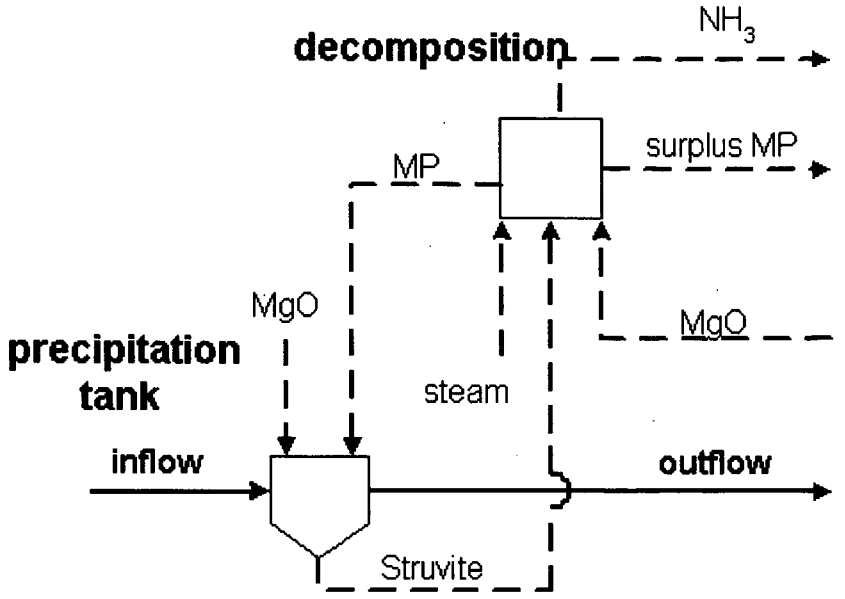

Figure 5: CAFR process for P recycling with increased NH_4-N withdrawal

SEABORNE PROCESS

The Seaborne process [14], [15] for processing of organic residues was developed by the Seaborne Environmental Research Laboratory (Figure 6); a pilot plant is in operation since February 2000 in Owschlag (Germany).

Within the Seaborne process, nutrients are recycled, and heavy metals contained in the raw substrate are removed from the nutrient circuit. Not only sewage sludge, but also co-ferments such as manure can be used as raw substrates. Besides a fertiliser and water which meets the discharge standards, electricity and thermal energy are produced in the end of the process; the heavy metals separated probably will have to be disposed.
The process consists of two blocs which are closely connected: A fermentation reactor together with a combined heating plant (CHP) serves to recover and to produce energy; process steps of biogas cleaning (**R**egenerative **G**as **U**pgrading and **R**emoval **o**f **H**eavy **M**etals) are integrated. Anaerobic treatment is completed by removal of heavy metals (RoHM) and nutrient separation (**N**itrogen **R**ecycling **S**ystem). An incineration plant is installed in order to treat the solids separated from the fermented biomass. Ashes should be fed back into the treatment process.

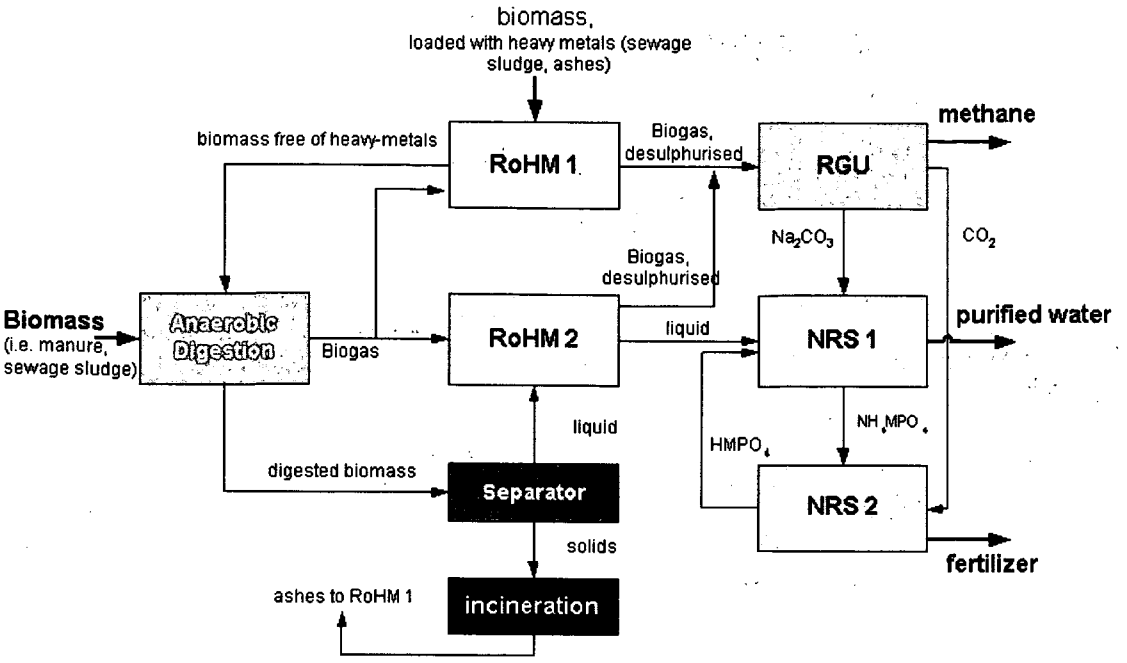

Figure 6: Flow sheet of the Seaborne process [14]

Some questions concerning this interesting and in this kind of configuration new type of process technology remain still open, especially with regard to the removal of heavy metals and the anticipated costs. Moreover, the plant safety of the complex technology has to be examined. Non-specialised personnel must be able to run the plant, so that this process can be spread widely. Only in that case relevant amounts of phosphorus can be recovered and therewith save the phosphate rock deposits.

CONCLUSIONS

A large number of technologies already do exist for the recovery of phosphates at municipal waste water treatment plants, which in Japan or in some European countries are partly already applied in industrial scale and more and more studied in Germany, too. Moreover, in Germany there is a great deal of discussion about the implementation of a recycling imperative combined with possibilities in refinancing the recovery plant.

However, the processes for phosphate recovery from sewage sludge cannot be seen separately from those for waste water treatment. The latter determine the usable potentials as well as costs of recovery. Based on the waste water treatment technology installed in Germany, the following three possibilities can be implemented in medium-term:

- Post-precipitation/ main-stream crystallisation of phosphate with precipitating agents which allow recycling in agriculture (e.g. lime [7] or MAP) or processing as raw material in the fertiliser industry (recovery rate about 75 %).
- Increased biological P elimination with downstream mono-incineration of the sludge and dissolution of phosphate from the ash ("Bio-Con process"; recovery rate about 85 %).
- Increased biological P elimination and recovery from the process water of the sludge treatment (e.g. PRISA process, recovery rate about 50 %).

The economic efficiency of the processes is determined especially by the phosphate content in the raw waste water and the logistics in reutilisation of the precipitated nutrients, and less by the process for phosphate recovery itself. This is due to the fact that the costs for necessary process changes at the waste water treatment plant are compensated by savings of precipitation agents.

Seen exclusively from the economic point of view (phosphate price), phosphorus recovery from waste water at the moment is not profitable. The costs are twice up to ten times the price of imported phosphates. This is due to the fact that decentralised phosphorus recovery at more than 10,000 municipal waste water treatment plants in Germany cannot be competetive, compared to the production of mineral fertilisers in a few big chemical plants.

For struvite precipitation of one kilogram phosphorus, for example, about 2 kg of magnesium oxide (MgO) must be dosed (beta = 1.5). The chemical costs are about 0.6 EUR/kg P, so they are in the lower range of the prices for the substituted iron or aluminium precipitants, which must no longer be used in advanced waste water treatment for the phosphate amount regained.

It depends on the market price of the phosphates extracted from deposits, to what extent processes for phosphorus recovery will become important in future. In the beginning of 2002, 28 US$ had to be paid for one ton of phosphate ore (P_2O_5 content about 26 – 34 %) [18]. This corresponds to a price of 0.24 to 0.32 EUR/kg P. The price for phosphate fertiliser in wholesale trade is approx. 1.0 EUR/kg P [19].

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INNOVATION OF ACTIVATED SLUDGE MODEL DEVELOPED BY IWA

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ABSTRACT

TMG (Tokyo Metropolitan Government) needs to remove nitrogen and phosphorus to meet the regulatory requirements and mitigate the eutrophication of Tokyo Bay, which is the receiving waters of the effluents. It has to be done efficiently under the tight budget. For this purpose, efficient operation of the biological nutrients removal processes is needed. TMG built new software to innovate Activated Sludge Model developed by International Water Association for its practical use. The new software is now under use at wastewater treatment plants in the downtown of Tokyo.

KEYWORDS

Activated Sludge Model (ASM), nitrogen removal, phosphorus removal, simulation

INTRODUCTION

Water pollution of enclosed Tokyo bay has been problematic, in spite of the achievement of full coverage of sewage system in Tokyo 23 wards in 1994, which is downtown of Tokyo and the most urbanized area in Japan. Especially in summer period, there occurs red tide phenomenon frequently. This phenomenon is considered to be eutrophication caused by pollution of nitrogen and phosphorus. These nutrients are partly coming from wastewater treatment plants (WWTPs). In order to meet public request and new strict regulation of nitrogen and phosphorus to WWTPs, TMG has to deal with the problem efficiently under the tight budget control.

Removal of nitrogen and phosphorus at WWTPs is commonly carried out with advanced biological treatment processes. However, they need longer hydrodynamic retention time (HRT) than conventional activated sludge processes. It is difficult to find extra-sites for introducing advanced treatment processes at WWTPs in urbanized areas such as Tokyo 23 wards.

TMG is now experimenting new technologies to remove nitrogen and phosphorus efficiently, while constructing full scale new advanced WWTPs using verified technologies. One of the new technologies is practical use of ASM (developed by IWA in 1993), which is referred in this article. ASM is applicable not only to advanced biological treatment processes but also to conventional activated sludge processes, if aeration is restricted at the beginning part of aeration tanks or if nitrification is enhanced.

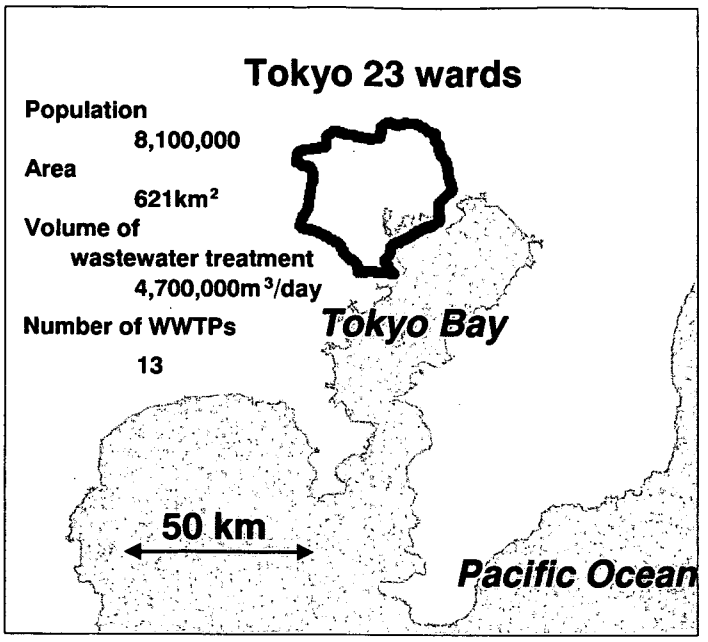


Figure 1 Outline of Tokyo 23 wards

At first, TMG regarded that practical use of ASM was impossible because of its complexity. However, ASM can be useful tool for efficient and effective removal of nitrogen and phosphorus because it enables operators to predict effluent water qualities by setting data on structures of bioreactors, water qualities of influent, and operational conditions. Therefore, TMG decided to adopt it by making innovation with new software for adaptation to the local and practical use.

METHODS

In order to utilize ASM at WWTPs regularly for operational purposes, the following requirements have to be satisfied.

The new software needs to be,

(i) operated in Japanese,
(ii) handled be operators with no knowledge about ASM,
(iii) based on the measured daily water qualities data,
(iv) and compatible with personal computers.

For the first requirement, graphical user interface (GUI) was developed. It evokes process control to the operators in a schematic way. Many commercial available software products based on ASM adopt CUI (character user interface) or poor GUI. This is one reason to avoid ASM software to be used by general engineers at WWTP.

Another reason for preventing practical use of ASM was the technical difficulties of ASM for ordinary operators of WWTPs. Operators have to understand and interpret the meanings of various equations and parameters and enter values in order to predict effluent qualities when they use commercially available software of ASM. It is impractical for operators to do so. These equations and parameters are incorporated into the software. Therefore, operators of WWTPs are free from setting of complicated parameters. All operators have to do is to enter measured water qualities and operational conditions. For advanced operators, functions to set the detailed parameters remain optional.

TMG have carefully considered in detail to establish the third requirement. The index for the organic components used in ASM is COD_{Cr}. However, COD_{Mn} and BOD are usually monitored as the index of organic compounds in Japan. The method for measuring COD_{Cr} can detect almost all of organic compounds while COD_{Mn} and BOD only detect readily degradable compounds. Moreover, COD_{Cr} has to be fractionated to six organic variables defined in ASM. In order to obtain the variables from COD_{Mn} or BOD, influent samples are examined through two steps. The first step is to convert measured COD_{Mn} or BOD into COD_{Cr}. The second step is the fractionation of COD_{Cr} to six organic variables. Some of investigated ways to convert measured data into ASM variables are taken in by the software.

The fourth strategy is also needed to be used the software widely in Tokyo 23 wards for improvement of water quality. As the performance of general purpose personal computers has been improved in a recent few years, special technologies are not needed for developing the software.

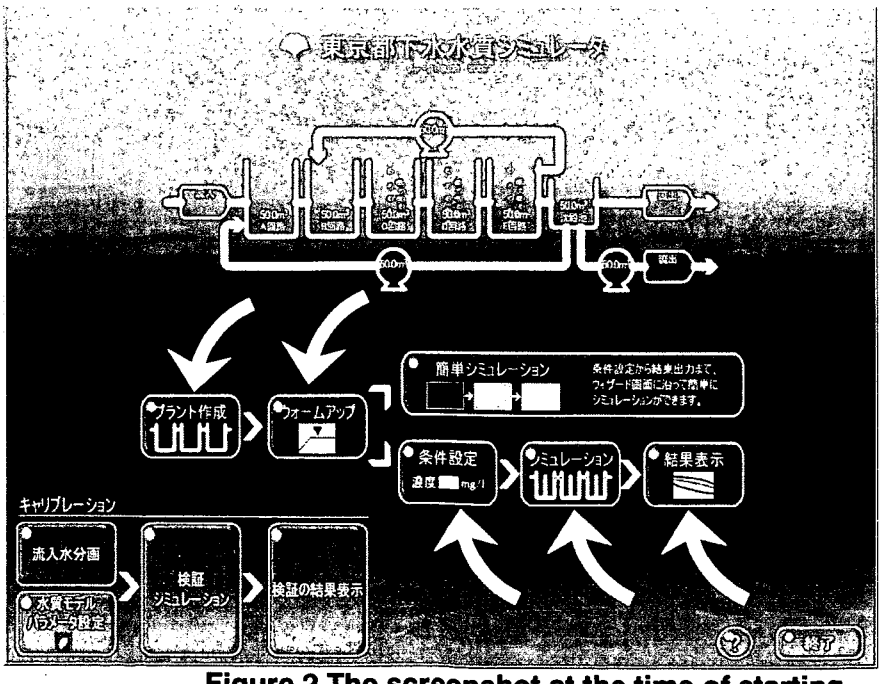
The simulation software predicting water quality of treated wastewater was built. Characteristic functions of the software are described in RESULTS section.

RESULTS

Characteristic functions and user-friendly operation screen equipped with the software are described below. These functions were built so that they are associated with demands of job sites. Comparisons between actual data and calculated data about WWTP are carried out to enhance the predictive accuracy.

The outline of the software operation method

The software has been built so that the general sewage engineers can operate easily only by watching its screen. The screenshot at the time of starting is shown in Figure 2. Pushing buttons can start each simulated processes, such as setting up, start-up and operation of an imaginary WWTP. The data needed for the simulation are promoted to input and the simulation is suspended if data are blanked. Thus, the simulation can be completed without any operational difficulties.



The arrows show buttons to start each simulated processes.

Figure 2 The screenshot at the time of starting

Figure 3 is a screenshot of an imaginary WWTP set up. The operation is very easy just like graphic software. It is possible to not only recreate actual WWTP but also design new type of WWTP which does not exist.

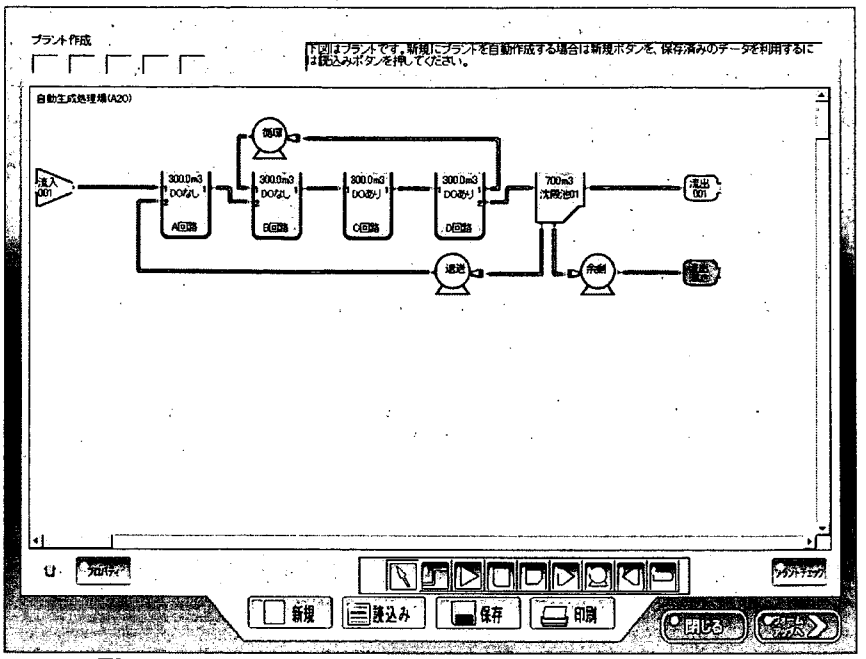


Figure 3 A screenshot of an imaginary WWTP

The data of water quality of influents and operational conditions can be input in spreadsheet form.

The simulation proceeds with calculated water qualities displayed. Once a certain condition of simulation is finalized, the required parts of the predicted water qualities as spreadsheet form can be retrieved.

If predicted data is far from actual data, recalculation is required with adjusted ASM parameters. However, much knowledge about ASM is needed to estimate what parameters should be adjusted and how much the numerical values of parameters should be increased or decreased. This software has a function that calibrates the parameters automatically for ordinary users. It is required just to input the measured data of effluent additionally.

The way converting measured data to ASM variables

In order to predict water quality of the effluent based on the daily measuring influent such as COD_{Mn} or BOD, it is needed to clarify the relationship between COD_{Cr} and COD_{Mn} or BOD and to establish the way to convert COD_{Mn} or BOD into COD_{Cr}. As results of studies of many samples at various WWTP, five ways to enter measured water qualities are provides to the software. The ways set up are as follows:

If measured data are COD_{Mn}, BOD or TOC, it is needed to convert these values into COD_{Cr}. As a result of the investigation at some WWTPs, conversion factors from COD_{Mn}, BOD and TOC to COD_{Cr} were obtained. According to the calculated results, these factors are applicable at WWTPs in Tokyo 23 wards.

Measured or converted COD_{Cr} has to be fractionated to six ASM variables at the next step. As the easiest way for users, fraction coefficients to six variables were established by the result of the investigation at some WWTPs. Just input of measured COD_{Mn}, BOD or TOC is

needed in this way. Contrary, the function to enter six ASM variables directly was also prepared. And the third way was equipped. This way has high accuracy same as entering ASM variables directly although the data needed to input is measured easily. The method is modified one of STOWA's. The fractionation method proposed by STOWA (Stichting Toegepast Onderzoek WAterbeheer, English name is "Dutch acronym for the Foundation for Applied Water Research") is the method of not performing the complicated OUR (oxygen usage rate) measurement. The new method eliminates some measurements from STOWA method to use practically. Only the input of COD_{Mn}, s-COD_{Mn}, BOD and concentration of acetic acid can obtain the prediction results with high accuracy by the modified method of STOWA's.

Thus, five input methods have been finally equipped, i.e. input of COD_{Mn}, BOD, TOC or ASM variables directly and the modified method of STOWA's.

The estimation of aeration rate for cost reduction

ASM model only deals with biological treatment processes. Other reliable models can be introduced additionally into the ASM software. The models for sedimentation tank are often introduced. The model to estimate the aeration rate was introduced considering the demands of job site, the accuracy of the model and the increase in calculation time after some studies of already confirmed models.

Since actual oxygen requirement (AOR) is calculated from ASM, defined value of either oxygen-solution rate or dissolved oxygen (DO) can yield another one. Comparing these values at WWTPs with calculated ones, the calculated aeration rate almost corresponded with the actual value in case of DO control. On the contrary, DO did not agree well with measured data in case DO is not controlled. As a result of these studies, the function to estimate the aeration rate was equipped, while the investigation to estimate DO has been continuing. An example of the calculation of the aeration rate will be shown at latter section.

Other functions of the software

Two more functions of the software will be described. The first one is the setting of "anoxic zone" at aerobic stage. More excess denitrification than theoretical calculation is often observed. If this phenomenon has occurred, the predicted result becomes less accurate. Because the phenomenon is probably caused by unevenness of DO observed occasionally at aerobic stage, the concept of "anoxic zone" can reproduce more accurate calculation.

The another one is the setting the concentration of nitrate reduced in return sludge. Denitrification at final sedimentation tank often occurs even though the phenomenon has been rarely regarded. This leads to more release of phosphate at anaerobic stage and sequential more ingestion at aerobic stage. This function can enhance accuracy for prediction of phosphorus removal.

TMG is still trying to introduce other functions to enhance the prediction accuracy.

Reproduced examples to improve water quality

Practical use of this software has been just started all WWTPs in Tokyo 23 wards. Therefore, there are no practical examples to change operational conditions and to improve the water quality of effluent on the basis of simulation results. Reproduced examples of the actual improvement with this software are shown in this section.

Phosphorus removal is difficult even with A^2/O process when the concentration of soluble organic compounds in influent to bioreactor is low. Actually, phosphorus concentration of

effluent was found relatively high at a certain WWTP with A^2/O process in Tokyo 23 wards. The observed and calculated phosphates in a certain period are shown in Figure 4. The calculated data are nearly in agreement with the measured ones. The average concentration is approximately 1.0 mg-P/L in this period. However, the desirable maximum concentration is also 1.0 mg-P/L. Some operational conditions have been changed for efficient phosphorus removal as a result after various attempts; those are the ratio of recycled nitrate, the ratio of return sludge, the volume of excess sludge to be excluded and the HRT at each stage. The ratio of recycled nitrate has been reduced, while the ratio of return sludge, the volume of excess sludge and the HRT at anaerobic stage have been increased. The calculated data using current average operational conditions is also shown in Figure 4. The predicted data are dramatically improved by changing operational conditions. Current water qualities are also around this level.

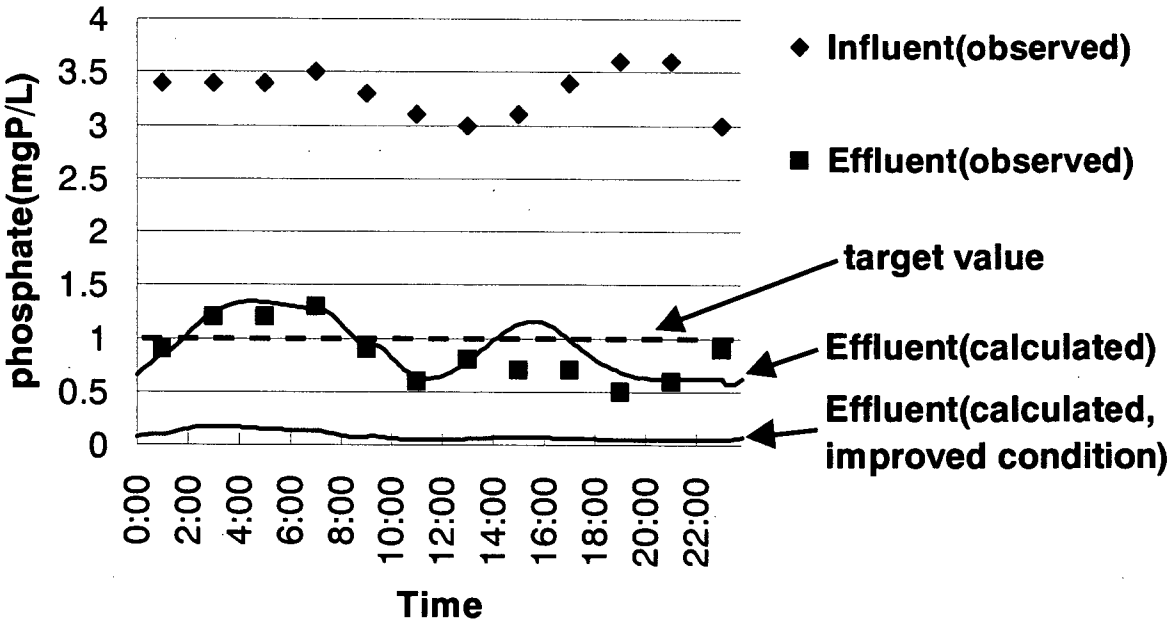


Figure 4 The observed and calculated phosphates

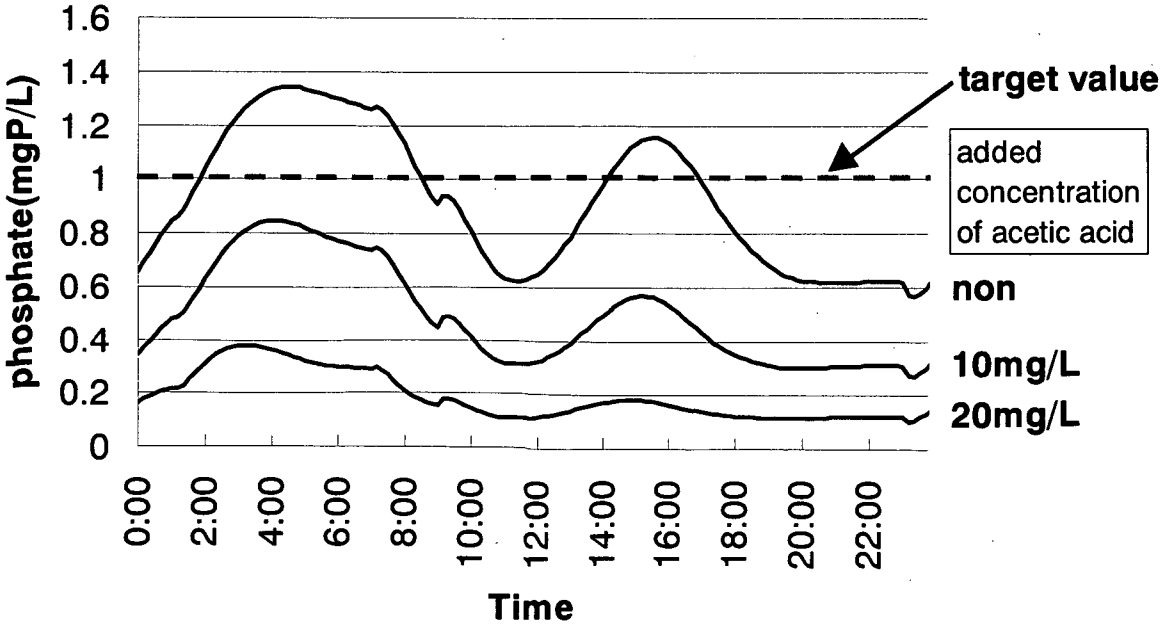


Figure 5 Predicted effect of acetic acid addition

The optimum operational condition can be also estimated when removal of both phosphorus and nitrogen is required. Water quality of ammonium is not so good in the improved case shown in Figure 4. If 1.0mg/L is demanded as maximum concentration about both phosphorus and ammonium, the software can confirm that medium condition of improved and unimproved conditions is recommended.

Another attempt can be also reproduced. Figure 5 shows the predicted data in case acetic acid is added at the inlet of the bioreactor. Addition of acetic acid at a concentration of only 10mg/L is also recommended when acetic acid is readily available.

This software also can be used to attempt cost reduction. The predicted and measured aeration rate at another WWTP is shown in Figure 6.

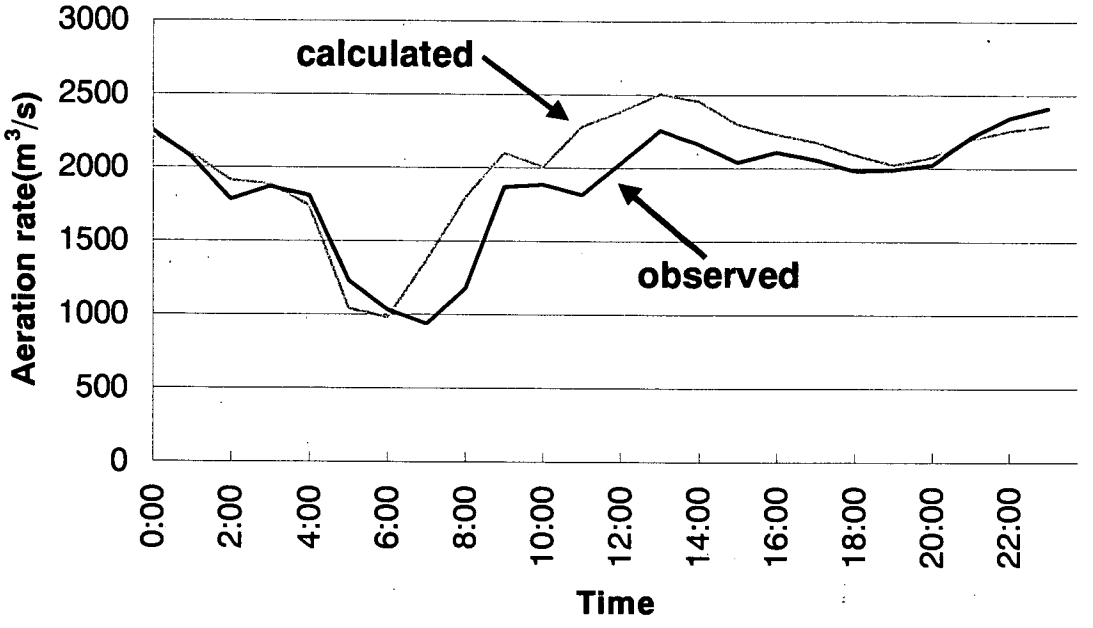


Figure 6 An example of aeration rate simulation

Additional calculation can be done at the WWTP for another challenge. The calculation results of various DO are shown in Table 1.

Table 1 Calculation results for cost reduction

DO (mg/L)	ratio of aeration rate	total nitrogen in effluent (mg/L)	phosphate in effluent (mg/L)
4.3	1	16.3	0.32
3.5	0.82	16.3	0.29
2.5	0.67	16.2	0.26

The results suggest that it is possible to reduce cost of aeration hugely by lowering DO without deterioration of nitrogen and phosphorus in effluent. This is because of lower actual oxygen-solution rate at higher DO.

It is not checked that all of these calculation results are right. However, the results described in this section indicate that the actual improved water qualities and the calculated ones with the software are very resemblance.

DISCUSSION

The outline of the software of innovated ASM of IWA for practical use and the way of forthcoming practical use are described in this article. The newly developed software has fewer functions. For example, the software does not equip the models for sedimentation tank, program languages, and so on. However, the functions of the software are enough for daily practical use at WWTPs. Other functions should be rather equipped, such as the function to predict appropriate volume of excess sludge in order to maintain desirable MLSS, DO of each tanks in case of no DO control and the concentration of denitrified nitrogen at sedimentation tank. These functions have been studied for introduction into the updated version of the software.

European countries have been utilizing ASM actively for designing and optimizing of WWTPs. Especially in the Netherlands, over 100 WWTPs have been optimized in detail. However, ASM has not been utilized by average operators for daily practical use at WWTPs. TMG led to build the software which can be used for the operators because TMG manages a lot of job sites by itself. TMG will face the extensive and unprecedented challenge to utilize ASM practically.

CONCLUSIONS

TMG have built the software for general engineers at WWTPs to predict water quality in effluent after bio-treatment. This software has functions to provide the information to improve water quality of nitrogen and phosphorus concentration. TMG has just started daily practical use of the software and enhances use of this software for daily management at WWTPs.

ACKNOWLEDGMENTS

This software is built by TMG in partnership with two private enterprises; Nihon Suido Consultants Co., Ltd. and Yaskawa Electric Corporation.

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ONLINE SIMULATION AND OPTIMISATION OF AN INTEGRATED SYSTEM - WASTEWATER TREATMENT PLANT AND SEWER SYSTEM

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ABSTRACT

Operation and building costs of wastewater treatment plants (WWTP) and sewer systems can be reduced by using an intelligent way of operation. At the WWTP there are several cost-intensive points in the treatment process that can be optimised, primarily aeration rates and pump rates. In a sewer system the size, position and operation of the stormwater tanks can be optimised. Finding out the most cost-effective operating method in consideration of all requirements on ensuring stable operation and compliance with regulations is hardly possible only by manual operation.

In this paper a forward-looking solution to optimise the operation of a wastewater treatment plant and a sewer system of 150.000 habitants based on a real time simulation model is introduced. With the help of a new optimisation tool of the WWTP in conjunction with real time control (RTC) of the whole sewer system it will be possible to smooth incoming flow rates and to operate the sewer system and wastewater treatment plant in the best way concerning costs and water pollution control.

KEYWORDS

Optimisation; real time control; online simulation; wastewater treatment plant, sewer system

INTRODUCTION

Higher environment quality standards lead to higher threshold values concerning the effluent of WWTPs and the discharges of combined sewer systems. For this the permanent increase in efficiency of existing WWTPs and sewer system is required. With conventional technics this normally results in higher building and operational costs.

This can only be avoided by using better technologies. Real time control (RTC) is one possibility, that can lead to reduced building and operational costs and better environmental and operational conditions.

By using RTC the system operation considers the actual situation in the system. Actual values, e.g. flow or nitrogen parameters, are measured to use them for online simulation and optimisation. To use the present values is especially important concerning the effectiveness

of systems with high dynamics of boundary conditions. The urban drainage system is such a dynamic system and therefore particularly suitable for RTC.

RTC of an integrated system, sewer system and sewage plant, is carried out from the Wastewater Association Obere Iller (AOI) in co-operation with the consultant engineers for sewer systems, sewage plants and control (iaks GmbH) and Paul Schaad Ingenieure in the South of Germany. Objectives are the reduction of investment and operational cost and an acceptable level of water pollution control. The project is supported by the German Federal Ministry of Education, Science Research and Technology.

For the WWTP an optimisation tool based on a real time simulation model of the WWTP and a computerized databank has been developed. The optimisation system always finds the best way to reduce the operational cost of by taking into account the dynamics of the incoming wastewater, the full capacity of the WWTP and the legal threshold values. The sewer system as well is operated with the help of an online optimisation tool based on an online simulation tool. In the case of rain the tools calculate the best effluent values of the stormwater tanks in order to fill all tanks consistent and to discharge as less wastewater as possible. The final aim of the project is to control both parts, the sewage system and the treatment plant, together to enable an optimum function of the entire system.

THE SYSTEM OF THE WASTEWATER ASSOCIATION OBERE ILLER

Description of the Wastewater Treatment Plant

The sewage plant situated in the South of Germany purifies the wastewater of 150.000 person equivalents.

The speciality of this WWTP are two aeration-tanks, each of them with a volume of 4000 m3 having the form of a nearly rectangular tank with the lengths of 150 m, a width of 4 m and a depths of 6 m, winding up to a spiral. This form presents an almost perfect plug flow reactor with the advantage of better biodegradation kinetics. Thus less volume is needed compared with the more common rectangular tank. The spiral construction leads to an inherent stability so that the wall thickness could be reduced to 40 centimetres. Altogether the construction costs were very low. The water flows inwards and the flow of internal recirculation has to be guided from the centre outwards, which is a shorter way to pump.

Because of the plug flow the reactor is sensitive to flow peaks but also very capable of being controlled. Divided into 5 elements, each equipped with a separate aeration unit, variable zones for different biological processes can be installed. By switching on and off the separate aeration units zones for nitrification and denitrification can be created as needed. By moving the position, where the internal recirculation is introduced a zone for phosphorus removal can be added.

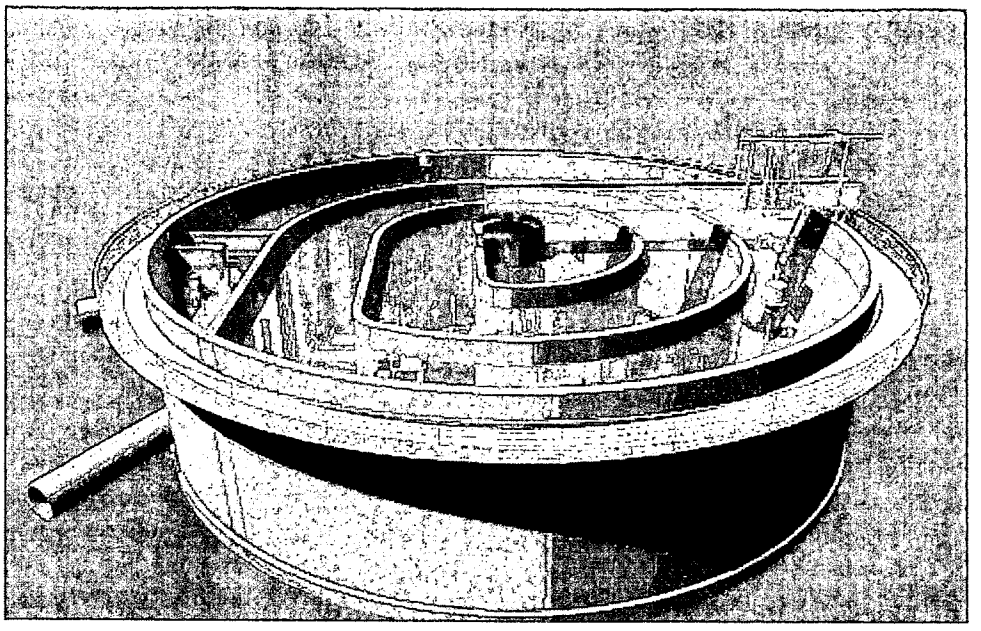

Figure 1 Special plug flow reactor on the WWTP of the Wastewater Association Obere Iller

Description of the sewer system

The system, mainly a combined sewer system, consists of 150 km sewer owned by the AOI, 300 km sewer owned by the communities, 33 stormwater storage tanks and 10 pumping stations. This system drains off the wastewater and the rainwater of an area of 56 km². A scheme of the system is presented in figure 2.

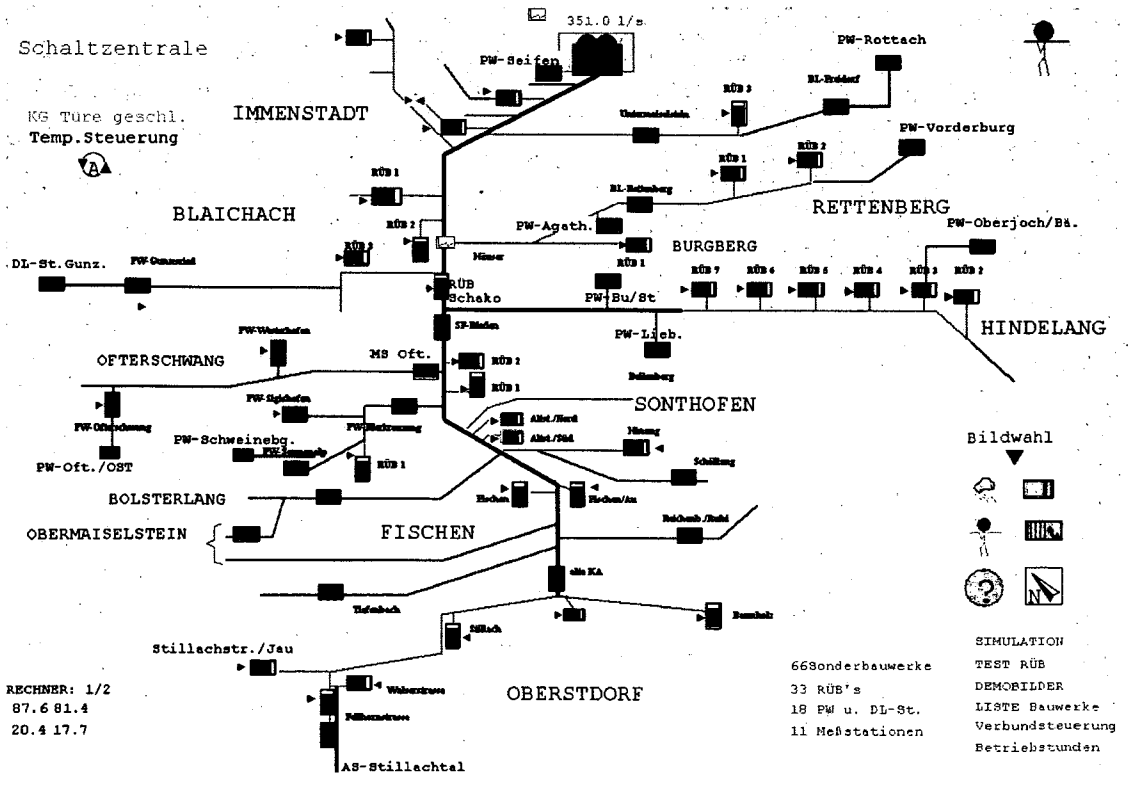

Figure 2 Sewer system with stormwater tanks, main sewers and the treatment plant

REAL TIME CONTROL OF THE SEWAGE PLANT

The system

In the frame of the described project the sewage plant is provided with RTC. There are control units, e.g. aeration units or pumps, and measurement units, e.g. for the water level, the flow and the concentration, which were managed by the control system.

The load of a WWTP depends on a variable wastewater quantity and composition. An operating method without consideration of the dynamic load leads to temporary capacity overload or derating. To use the total capacity of a WWTP becomes more and more important considering the aspects mentioned above. Aeration and pumping rates have to be adapted to the dynamics of the wastewater composition and energy cost.

Furthermore there are a lot of conditions to be fulfilled to ensure a stable operation i.e. a fixed dry-solid content in the aeration tank on the one hand and to keep effluent standards on the other hand. Considering all these requirements it is no longer possible to find out the most cost-effective operation by manual control only. An overall optimisation of the operating method of a WWTP will be necessary.

The online simulation model

The simulation model is based on the Activated Sludge Model No. 2d, ASM2d (Henze et. al., 1999). There are 100 input signals describing flow rate and composition of the incoming wastewater as well as parameters of the current operation on the WWTP like excess sludge rate. These signals are coming from online measurement on the WWTP. The simulation keeps starting new runs based on the latest values every 15 minutes. That way 1000 output signals are created, representing the actual state of the WWTP. The finally achieved state is the basis for the calculations of the optimisation tool. Furthermore the simulation offers parameters in real time that can not be determined by measurement, e.g. the sludge age or the degree of degradation of each tank. The model updates itself by comparing the fixed dry-solid content of the aeration tank in the simulation with measured values.

The first version of the online-simulation-model was launched one year ago. During this time the simulation-results were in good conformance with measured values. Nevertheless it is still necessary to evaluate manually the simulation results and to update various settings in the simulation model for example growth of biomass, to adapt the model to reality.

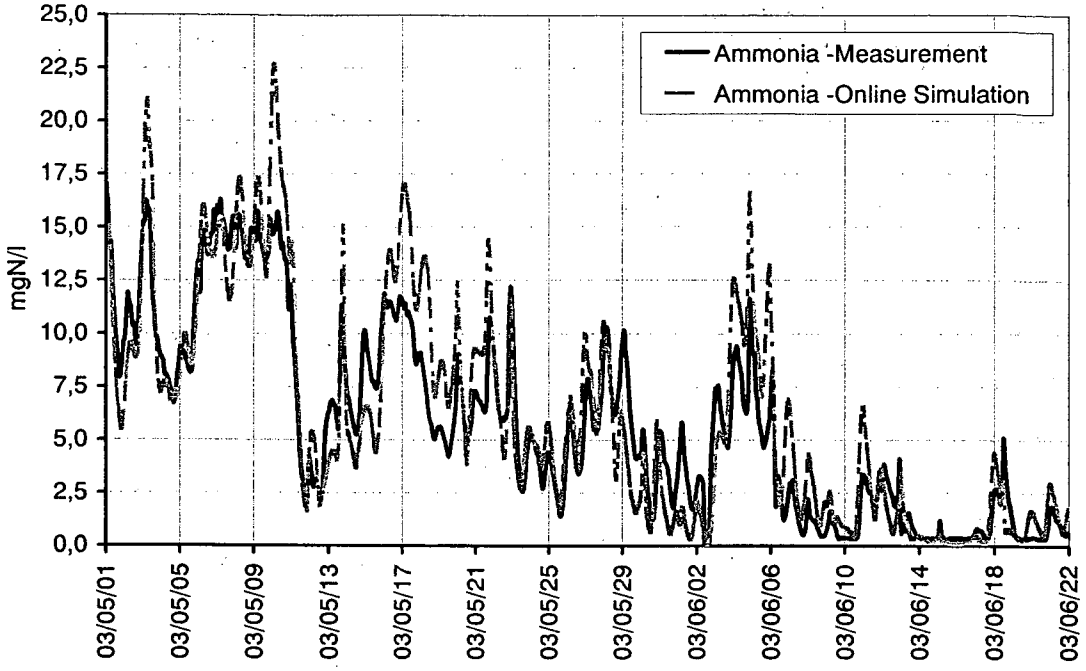

Figure 3 Results from the Online simulation compared with measured values of one month (ammonium nitrogen concentration in the effluent, 2 h time interval)

The optimisation tool

The optimisation tool is based on the online simulation model. With the latest state of the WWTP created by the online simulation the optimisation tool calculates the most cost-effective way of operation in an iterative procedure. The objectives of the optimisation are incorporated in a cost function. These objectives are

1.) Selected "optimiseable" variables, for example pumping rates
2.) Conditions that have to be fulfilled, first of all effluent standards

Every control object of the cost function has a special weight depending on its importance and effects. The minimum of the cost function has to be determined. This is done by changing selected "optimiseable" variables within an admissible range.

If necessary further control objects can be added, e.g. to limit the deviation from the desired concentration of total suspended solids in the aeration tank. Also further changeable variables like the ones in Figure 4 can be added as requested.
To calculate and propose the optimised values the quantity and composition of the influent has to be forecasted for one day. This is done by taking into account the forecast of the flow rate from the sewer system simulation and by using typical time variations in the course of a day for the most important wastewater ingredients.

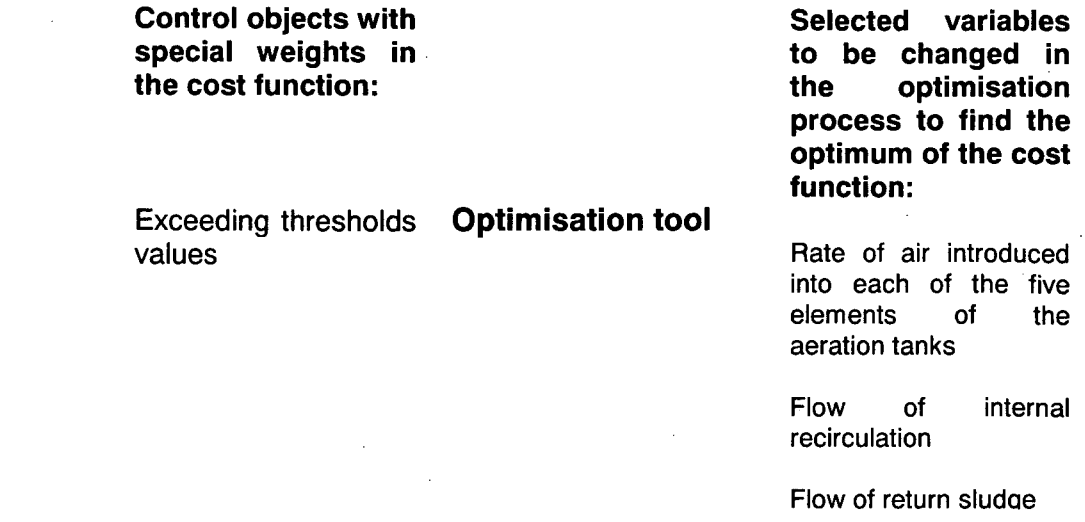

Figure 4 Changed "optimiseable" variables and control objects of the optimisation process

Example for a sewage treatment plant optimisation

The optimisation tool has been examined offline using real data input from the WWTP. In a first step the influence of all weighting factors shown in Figure 4 has been tested. It could be seen, that these weighting factors are all very sensitive and allow to adjust the optimisation tool precisely. The following figure exemplarily shows results from test runs with influent data from different days. For each day the curve of the reached maximal effluent value is shown by different costs for exceeding the effluent standard of 13 mg/l. It can be seen, how these costs control the optimisation results.

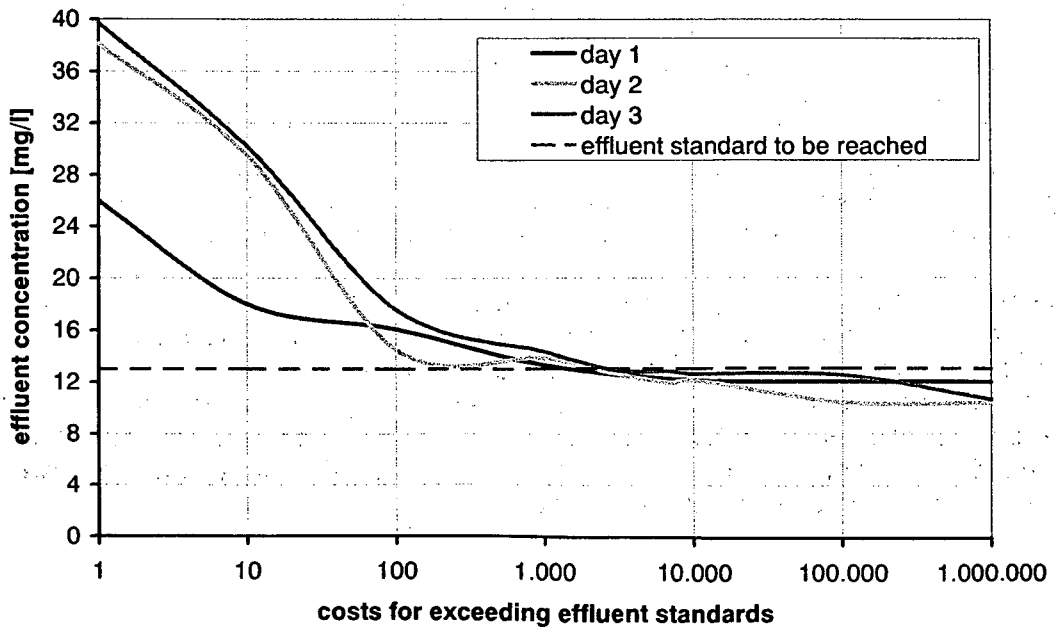

Figure 5 Maximal effluent ammonium nitrogen concentration by different costs for exceeding the effluent standard

In a second step of the offline test stage, the costs that can be saved with the optimisation were tried to evaluate. A precise statement cannot be given until the optimisation has been operating in real time over a longer period. First results can be given concerning the aeration rate, that has to be introduced into the aeration tanks. The optimised air rate is up to 20 percent lower compared to the operation without optimisation.

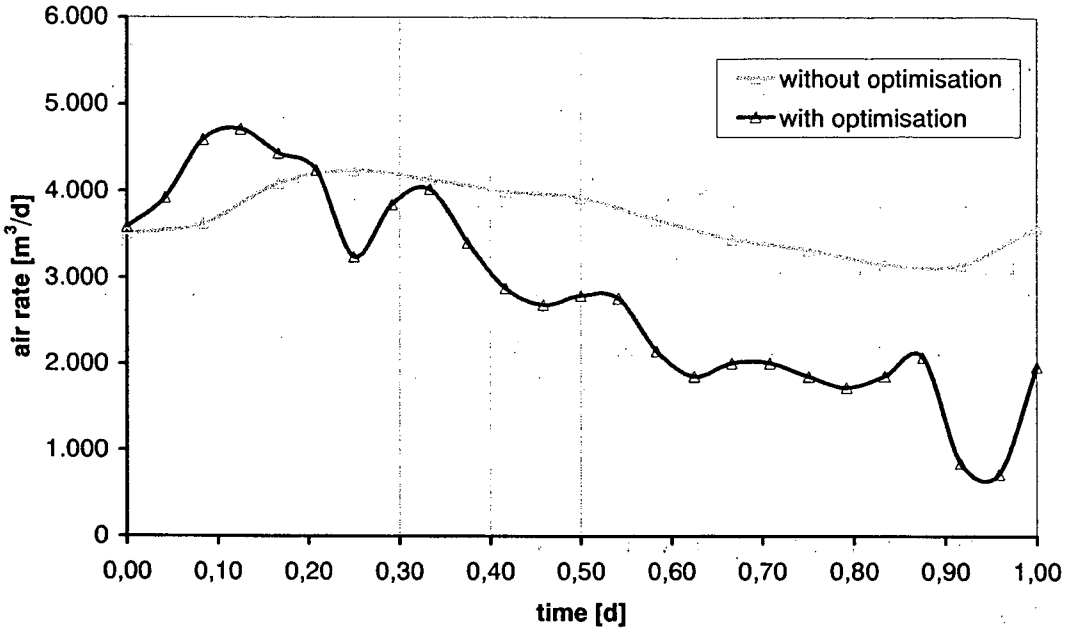

Figure 6 Air rate to be introduced into the aeration tanks with and without optimisation, test run with input data from one day in November 2003

Databank

A special computerized databank provides a basis for all mentioned applications. All data from online measurements on the WWTP are first accumulated at the process control system of the plant and then transferred to the databank. The databank stores and handles all values and provides the simulation model with all necessary inputs in real time. Furthermore the databank offers special functions:

- Data validation
- The real time calculation of parameters, that can not be measured, particularly specific components of the influent that are necessary for the ASM 2d
- Preparation of replacement values in order to provide the simulation model with data in case of failure of a measuring instrument

- Data validation
- The real time calculation of parameters, that can not be measured, particularly specific components of the influent that are necessary for the ASM 2d
- Preparation of replacement values in order to provide the simulation model with data in case of failure of a measuring instrument

All simulation results are also stored in the databank, which at last connects the online simulation with the optimisation tool. The results of the optimisation are also stored in the databank and transmitted into the operation process of the WWTP.

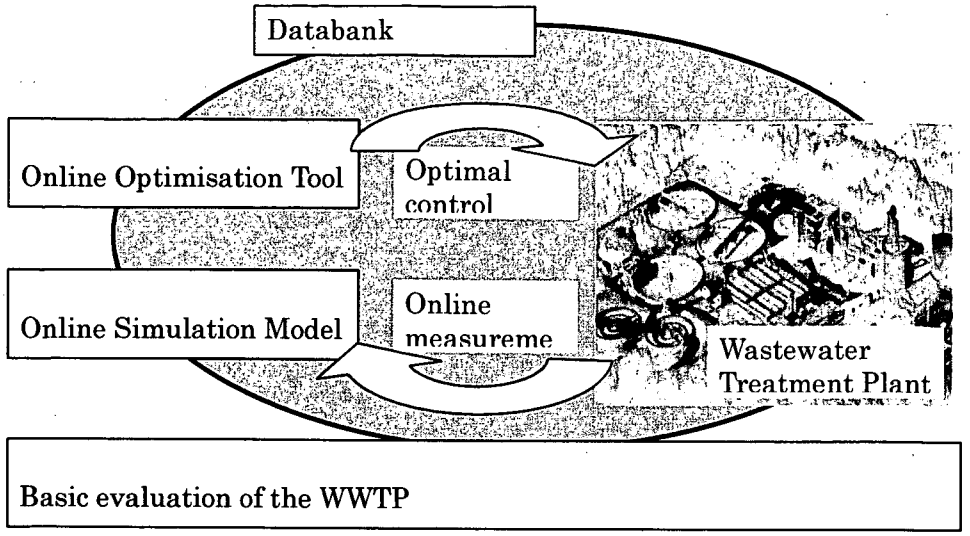

Figure 7 Cooperation of all tools of the real time control of the sewage treatment plant

REAL TIME CONTROL OF THE SEWER SYSTEM

The system

In the sewer system regulating gate valves and measurement stations for the water level and the flow are installed. All values, e.g. the opening degree of the slides, the flow and water level, are managed at the process control system. All important gate valves can be moved by it from the control room.

Online optimisation

During rainfall a simulation software calculates the hydraulic processes at the surface and in the sewer synchronously to the operation of the sewer system. Based on the rainfall data from the rain gauges a surface and sewer system simulation determines the future values of the influent into the stormwater tanks every five minutes. The simulation is faster than real time, that means that the states were forecasted.

The forecasted values as well as the measured values are basic data for the optimisation software. The optimisation tool calculates the set points for the gate valves with the objective to find the best settings for the actual state of the system. With the help of the process control system these calculated states were transmitted to the local regulation units. The simulation and optimisation system is presented in figure 8.

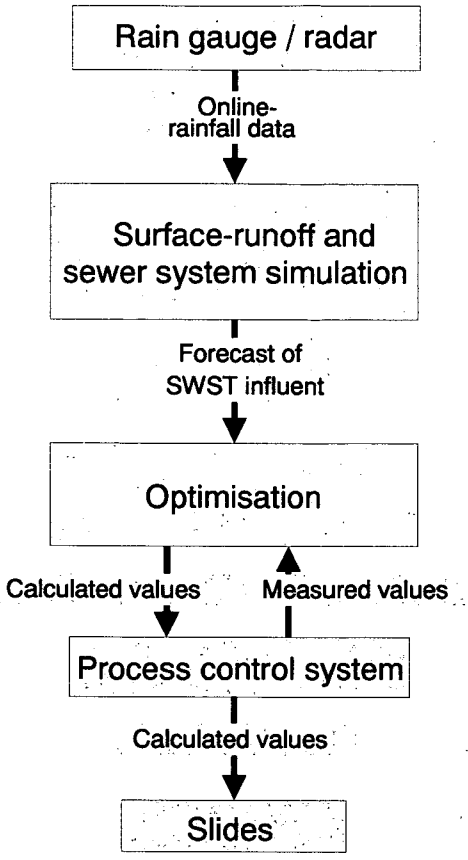

Figure 8 Optimisation of the sewer system

The systems are based on RTC. A RTC strategy has the following advantages:

- High degree of effectiveness due to individual treatment of every single rainfall
- Flexibility concerning the changes of control objectives
- Flexibility concerning the integration of further system parts
- Good transferability to other systems
- Consideration of failure (e.g. of a single gate valve)

The objectives of the optimisation are incorporated in a cost function. Every element of this function has a special weight depending on its importance and effects. For the optimisation the minimum of this cost function has to be determined. Control objectives are:

- Minimising the discharge volume in the receiving water
- Prevention of flooding
- Prevention of abrupt and continuously variations of the set points
- Uniform filling degree of all stormwater tanks

Example for a sewer system optimisation

To get an impression of the effects of the RTC in the sewer system a result of a simulation with and without RTC is presented in figure 9.

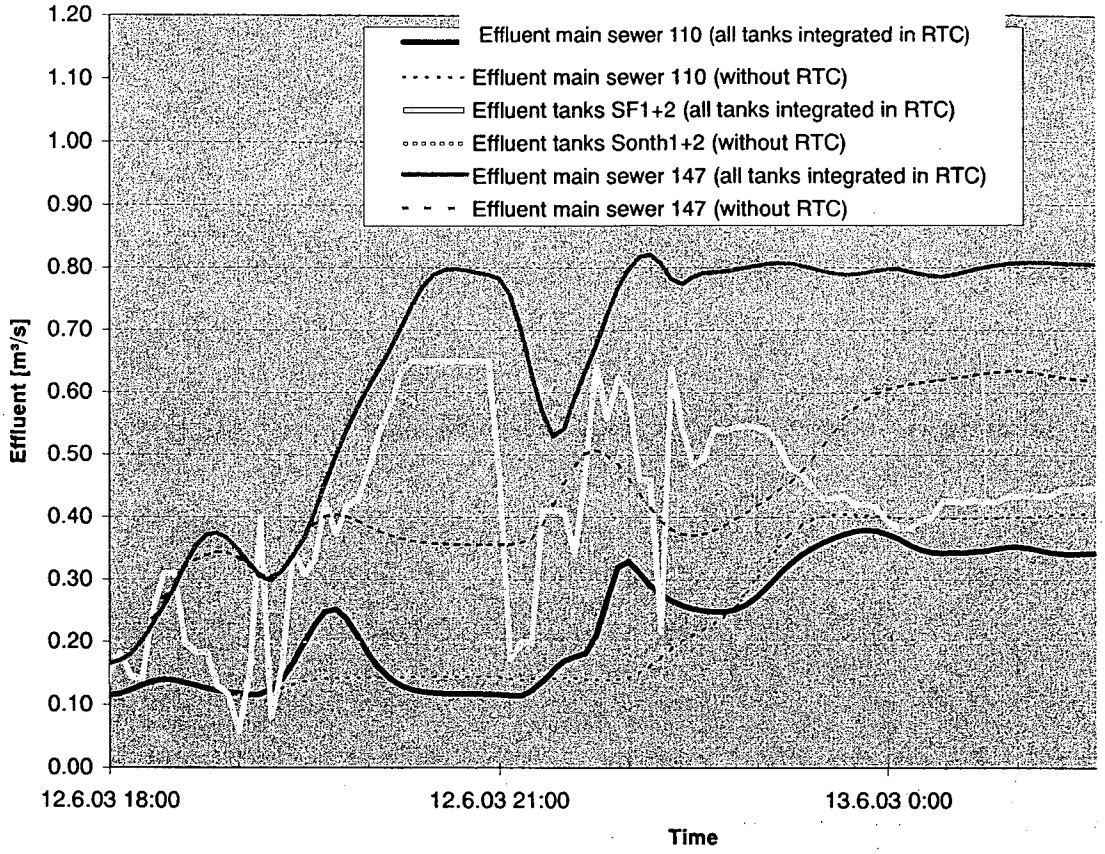

Figure 9 Effluent at different places of the sewer system with and without RTC

In figure 9 the effluents of three different places in the sewer system are shown. The two curves on the bottom show the effluent in the main sewer before the discharge of the effluent of the two stormwater tanks Sonth1 and Sonth2. The curve on the top shows the effluent after the discharge of the tanks. In all cases the thick lines are the result of the simulation with Real Time Control. The dashed lines are the result of the simulation without RTC. With RTC the effluent to the WWTP at main sewer 147 (including the effluent from main sewer 110 and the tanks Sonth 1 and Sonth 2) is higher than without RTC. This leads to a higher impact of the WWTP, that is capable to deal with this effluent in a acceptable way, and to a reduction of the discharge of the tanks into the receiving water. In this case the reduction of all tanks upside the point main sewer 147 is about half of the total discharge. With integration of RTC 3470 m³ were discharged in the receiving water, without RTC 6887 m³. Of course this result is only valid for this specific rain. In other cases the reduction can be lower.

REAL TIME CONTROL OF THE ENTIRE SYSTEM

The optimisation system for the entire system, the sewer system and the sewage plant, is presented in figure 10. Concerning the control objectives of this entire system you have to be aware that some control objectives of the pure sewer system or treatment plant control are contradictory. For example, the consequence of the control objective minimising the discharge volume consists in an increased flow to the treatment plant. But it could be possible, that the treatment plant has no capacity at this moment. In this case it is necessary to prioritise the objectives. The duty of the optimisation tool is to balance out all the objectives regarding to an optimum operation of the sewer system.

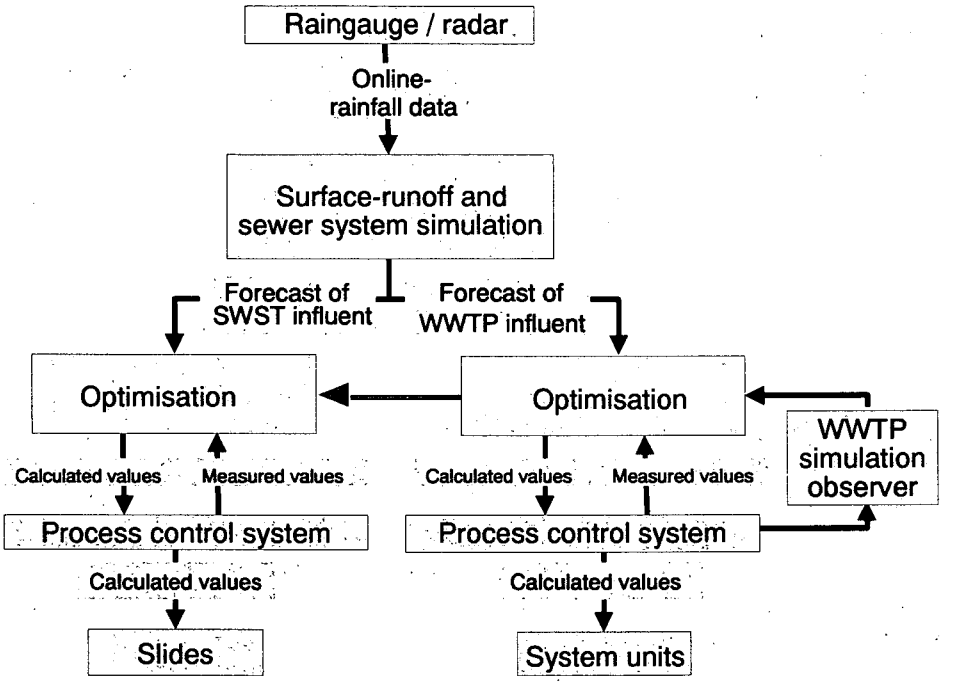

Figure 10 Scheme of the entire optimisation system

One aspect concerning the RTC of the entire system, sewage treatment plant and sewer system, is the hydraulic capacity of the sewage treatment plant. The hydraulic capacity depends on the hydraulic capacity of the secondary settlement tank, that is depending on the characteristics of the sludge. The maximum acceptable flow into the sewage treatment plant is calculated with an equation containing the sludge volume value. The actual value from the sewage treatment plant is available in the databank. This value is used to calculate the maximum flow into the WWTP. This maximum value is considered in the sewer system optimisation.

Another aspect concerning the RTC of the entire system is the calculation of the proposed flow into the WWTP in the case of rain. This forecast enables a good adjustment of the pumps and aeration units with view to low emission values despite of the disadvantages of rainfall, e.g. a hydraulic peak. The data exchange is carried out with the help of the database. The forecast is calculated with the simulation tool of the sewer system. The results were transmitted to the database. The optimisation tool of the sewage treatment plant access this values from the database and uses them for the next optimisation process of the WWTP.

STATE OF THE PROJECT UND PERSPECTIVES

The hard- and software components for the simulation and optimisation of the real time control system of the sewer system are already implemented. Some areas are already included in the controlled system. The other areas were tested offline and included in the online-system step by step. The hardware for the sewage plant optimisation is implemented. The software is tested offline at the moment. Then it will be integrated in the system. After both parts, the real time control system of the sewer system and that of the sewage plant, are working well, they were linked with each other.
Financial investigations would show the reduction of the operational and building costs effected by the online optimisation.

As the optimisation tool is a rather open system nearly all system elements and aspects can be integrated by adding to the cost function. The variation of the weight of the different elements of the cost function enables the consideration of the different aspects more or less.

The online optimisation tools allow the best and most cost effective operation. For the design and planning offline optimisation tools are used. Therewith e.g. it is possible to define the available capacity of an existing WWTP or sewer system and to detect those variables which can be optimised.

ACKNOWLEDGEMENT

The realisation of the projects is enabled by support of the German Federal Ministry of Education, Science Research and Technology. With this financial help it was possible to examine and develop the control strategy and to put the theories into practise, in spite of the financial risk of the development and realisation of a new technology putting into practise the first time. Moreover such a project can not be handled well without the help and engagement of all participants, the operators, i.e. the team of the Wastewater Association Obere Iller, and the members of the planning and management teams.

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Sewage Sludge Carbonizing System and Properties of Carbonized Products

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ABSTRACT

Carbonized products derived from organic sewage sludge are attracting attention as a novel material with possibilities for various utilization because of similar in properties to that of charcoal. Up to now, the sewage sludge has been disposed after dehydration, and also the incinerated ash of it has been utilized as feedstocks of Portland cement and construction materials. These utilizations, however, has no growth potential in the future.

In this paper, the carbonization system of sewage sludge, properties of its carbonized products and utilization methods are described. The materials are expected as new utilization forms, because of their characteristic properties such as high porosity, low density, highly absorptive capability and so on. The soil conditioner, dehydrating auxiliaries and deodorizer are studied as effective utilization candidate.

KEYWORD

Utilizations, Carbonized

CARBONIZATION PROCESS

Figure 1 and 2 show structure of carbonization furnace and flow sheet of carbonization system, respectively.

Three types carbonization furnaces are used in the experiment, that is, external heating type rotary kiln, external heating type screw kiln and internal heating type rotary kiln.

Charge after drying or direct charge is adopted as the feeding procedures. In the case of the external heating kiln, the sludge is supplied to a rotary dryer and dehydrated at 700 ℃ with hot gas from the air furnace. After the water content of the sludge in the dryer is

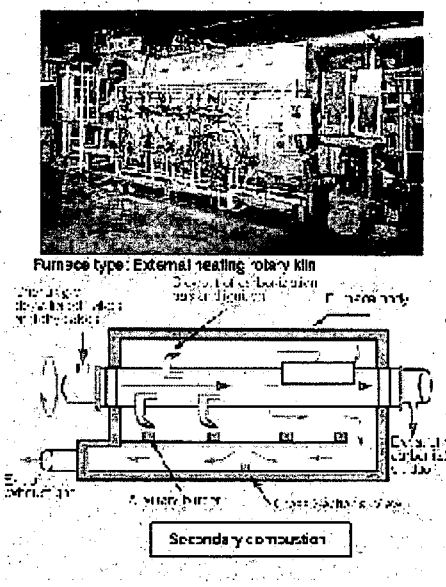


Figure 1 Structure of Carbonization furnace

Note : The sludge that was adjusted to contain approx. 40% of water in the drying furnace is baked in the retort at 700℃

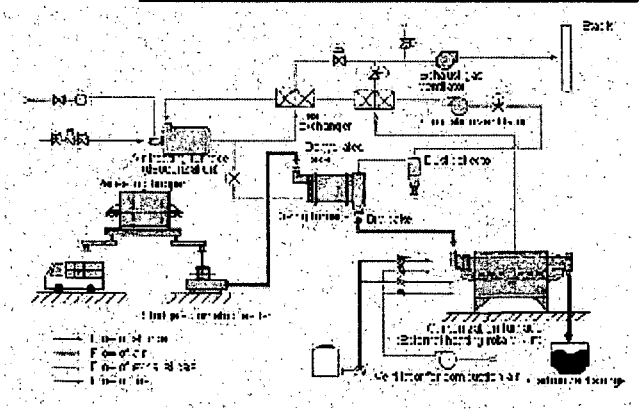


Figure 2 Flow Sheet of Carbonizing System

Note : The main system consists of a hot air furnace, a dryer and a carbonization furnace.

reduced to 40%, it is introduced into the carbonization furnace. The carbonization furnace contains a retort (rotary kiln), in which the sludge is carbonized at high temperature with shutting off the air. Exhaust gas treatment for oxidative degradation of generating odor and decomposition of residual substance are carried out in the external heat chamber, in which temperature keeps at a certain level. The retort rotating at 2-3rpm conveys the sludge to the rear end in 20 to 30 minutes. The carbonization gases such as methane, ethylene and carbon monoxide generated from heat- treated sludge are utilized as fuel of the resort.
The carbonized materials produced by carbonizing operation in reduction condition at high temperature possibly generate heat by oxidation if it is exposed in the air.
To avoid this phenomenon, the heated materials are indirectly cooled to the room temperature and then stabilized by water humidification before utilization.

PROPERTIES OF CARBONIZED PRODUCTS

1. Reduction of weight by carbonization of organic sewage sludge

Figure 3 shows weight change of water, organic substance and ash during carbonization process. 100-weight part of dehydrated cake is reduced to 25.7 and 5.8 weight part through drying and carbonization process, respectively. Namely, carbonization process reduce the volume of dehydrated sludge with 83 % water to 1/18. During the carbonization process, approximately 80% of organic substance in the sludge volatilizes as gas through carbonization and the remaining substance of approximately 20% is immobilized in the carbonized products.

Almost oxygen and hydrogen in the dehydrated sludge gasify through carbonization and approximately 70% of carbon, which is main element in dry solid substance, also gasifies but 30% of it remained in the carbonized products. The selective immobilization of carbon through carbonization is also confirmed by the fact that the carbon content of the organic substance in carbonized products accounts for approximately 80% which is higher value compared with those of dehydrated and dry cake as shown in Figure 4.

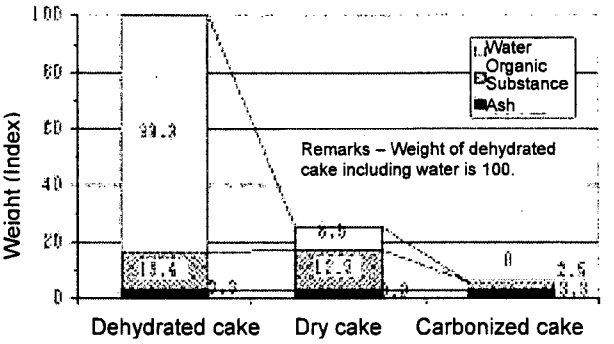


Figure 3 Weight Change of Sludge by Drying and Carbonization Treatment

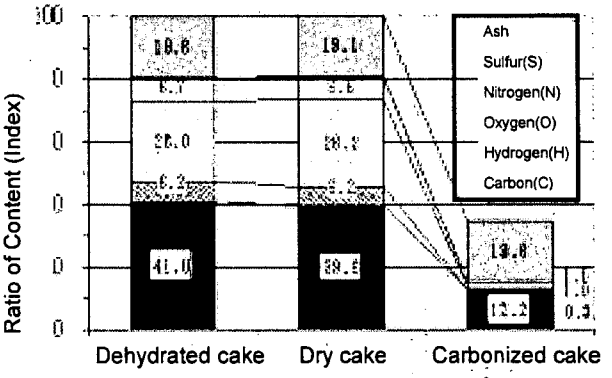


Figure 4 Change in Ratio of Content of Organic Substance by Drying and Carbonization Treatment

Note: The moisture percentage of dehydrated cake is reduced to approximately 6% from 80% by carbonization treatment.

2. Physical Properties of Carbonized Products

The typical physical properties of the carbonized products are shown in Table 1. Activating treatment increases specific surface of charcoal. Compared with normal charcoal and activated charcoal, the average pore radius of carbonized products is similar to those of normal charcoal and 5 times as big as the activated charcoal, partially because no activating procedure is applied to the products. The total pore volume of the products is less than half of that of the activated charcoal. The specific surface area of the products is almost same as that of normal charcoal, and less than 10% of the activated charcoal. The bulk density is as light as 0.35 to 0.59. Although the total calorific value is 12 to 13 MJ/kg, which is equivalent to that of charcoal (30 MJ/kg)

Thus, in view of the fact that the properties of carbonized products are considerably similar to those of charcoal, the application to soil conditioner and deodorizer can be considered as effective utilization.

Table 1 Physical Properties of Carbonized Products

	Unit	Carbonized Products	Reference	
			Charcoal	Activated Charcoal
Water	%	1.78	1～2	1～5
Ash	%	42.0～57.8	9～15	1～5
Volatile Component	%	5.57		
Bulk Density		0.3～0.59		
Specific Surface Area	m^2/g	23.2～114.2	50～400	Approx. 1000
Total Pore Volume	ml/g	0.062～0.122	0.05～0.1	0.46
Average Pore Radius	Å	53.5	37～6500	8.5～10
Carbon	%	23.9～36.17	98	90～98
Nitrogen	%	1.9～5.33		
Hydrogen	%	0.62～2.86		

Note: The carbonized product is a material having a specific surface area and pore volume similar to those of charcoal.
Its carbon content is about 40%, which is smaller than that of charcoal.

3. Content of Metal Element

All tests on both elution of heavy metals and content of six elements, including total mercury, of the products reveal to meet the standard values designated under "Fertilizer Control Low". "Administrative Standard with Regard to the Prevention of Accumulation of heavy Metals etc. in the Soil for Agricultural Land" states that the concentration of zinc in the soil should be kept below 2.5 to 3 times through the carbonization of dehydrated sludge resulting the decrease of organic substance content, for application of the carbonized products to agriculture. Careful attention should be made to mixing ratio with the soil, so that they are used within the administrative standard.

UTILIZATION OF CARBONIZED PRODUCTS

Effective utilization of carbonized products taking advantage of its properties is being lead for soil conditioner in green farms, dehydrating auxiliaries, deodorizer, compost additive and snow melting agent.

1. Uses in Green Farms

The following are vegetable and flower cultivating experiments results conducted to investigate the applications to green farms.

Properties for Application to Green Farms

Chemical Properties

Studies have been conducted on three different types of carbonized products, which were derived from different amount of polymer-dehydrated sludge as shown in Table 2. "Soil Subcommittee of Japanese Institute of Landscape Architecture" recommends as vegetation soil that PH is alkalescent because for improvement of acid soil. Electric conductivity (RC) is an index indicating the concentration of the salts in the soil. Small EC value of products means that concentration of salts in the products is low and has no recognizable harm to plants. The positive ion exchange capability is an index indicating the ability of soil particles to absorb nutrition salts (Fertilizer remaining ability).

No particular effect has been observed in this respect by mixing carbonized products. However, carbonized products have physical absorption ability in addition to chemical absorption, and they showed effective fertilizer retaining ability in the actual experiments on plants

It was found that the sewage sludge carbonized products contain phosphor in a form which plants easily absorb. This is the unique property of the products that is not in other sludge materials.

The other value described in Table 2 are within the range desirable for vegetation soil, therefore, the improvement of the soil can be expected by mixing carbonized products with the soil.

Table 2 Chemical Properties of Carbonized Products (for Application to Green Farms)

	Unit	Carbonized Product 1	Carbonized Product 2	Carbonized Product 3	Soil Standard
pH		7.9	7.1	7.5	4.5~8.0
Electric Conductivity	s/cm	0.16	0.20	0.15	1.0>
Positive Ion Exchange Capability	cmol/kg	5.6	6.8	7.5	6<
Phosphate in Available Form	mgP_2O_5/100g	150	54	150	10<
Phosphate Absorbing Factor	mgP_2O_5/100g	240	—	110	1000>

Note: The carbonized product is alkalescent and has excellent water permeability. It contains phosphor in abundance in a form that can be easily absorbed by plants, one of the features of sewage sludge carbonized products.

Physical Properties

Table 3 shows the results of analysis on the physical properties of carbonized products, the soil and products/soil mixture. It is said that the desirable coefficient of standard water permeability of the soil for plant cultivation is 10-4 cm/s and above. The farmland used in this experiment of vegetable cultivation had rather poor water permeability coefficient in the order of 10-5 cm/s. The coefficient was improved to 10-3 cm/s order by mixing carbonized products with the farmland soil by 30%. The suitable ratio of gaseous phase in the triphase distribution is 13 % and above for farmland. The gaseous phase ratio of the soil was raised to 21% from 8.9% by mixing carbonized products by 30%. Further, the effective water retaining volume was improved to as high as 100 l/m3 from 66 l/m3

Table 3 Physical Properties of Carbonized Products and Soil
(For Application to Green Farms)

		Unit	Carbonized Product	Soil	Mixed Soil*
Coefficient of Saturated Water Permeability		cm/s	—	1.3×10^{-5}	2.0×10^{-3}
Triphase Distribution	Solid Phase	vol%	24.7	45.8	39.3
	Liquid Phase	vol%	38.9	45.3	39.3
	Gaseous Phase	vol%	36.4	8.9	21.4
Effective Moisture	pF1.8～3.0	l/m3	100	42	66

* : Soil was mixed with carbonized products by 30%.

Note: By mixing carbonized products with the silty soil, the gaseous phase portion has increased, and as a result, the soil has been improved to provide an environment suitable for culture.

Examples of Utilization

(1) Application of the carbonized products to Carrots, Chinese Cabbages (Konatsuna) and Kidney Beans cultivation

In order to study the effect of the soil improvement, the farmland was plowed to depth of 15 cm and carbonized products were mixed with the soil at the ratio of 0%, 10% and 30%. Then, the cultivation experiments have been conducted on carrots, Chinese cabbages and kidney beans. In the experiment of carrots, the higher the carbonized products mixing ratio increased, the heavier the total and substance portion weight became. The results show that the carbonized products are believed to have contributed to the improvement of physical properties and the fertilizer retaining ability of the soil.

On the other hand, in the case of Chinese baggage, the higher the mixing ratio of carbonized products was, the lighter the weight of surface portion was, the bigger the ratio of subsurface portion to the entire plant. These differences occur characteristically to vegetable plants when the nutritious substances are supplied slowly and effectively. It is believed that the difference is taken place because the nutritious salt is temporarily absorbed and retained by the carbonized products, and as a result, the fertilizing effect in the soil changed to slow and effective pattern. The beans family such as kidney beans is generally capable to absorb nitrogen from the root nodules formed at the root in symbiosis with a microorganism having the ability of immobilizing nitrogen (ability to immobilize the nitrogen in the air for utilization as a nutrient)

The higher the mixing ratio of the carbonized products was, the heavier the weights of subsurface portion and the root nodule were. The results show that the carbonized products contributed to improvement of air permeability.

The pore structure and chemical properties of the products are believed to be suitable for the multiplication of the symbiotic microorganism (Table 6).

Table 4 Weight of Carrot by Organ, S/R Ratio* and Yield Index

	Weight of root portion, raw state (g)	Weight of root portion, dry state (g)	Weight of surface portion, raw state (g)	Total weight, dry weight (Physical weight) (g)	S/R Ratio	Yield Index
Control	141.4	14.22	5.56	19.78	0.391	100
C10%	164.4	15.34	6.52	21.85	0.425	116
C30%	177.2	17.49	7.40	24.89	0.423	126
Calcium Carbide	134.9	-	-	-	-	96

* : S/R Ratio means the ratio of the weight of surface portion to the weight of subsurface portion. The more abundant the nutrient in the soil is, the higher S/R is.

Table 5 Height, Surface and Subsurface Weights, and S/R Ratio* of Chinese Cabbages

	Height (cm)	Weight of Surface Portion(g)	Weight of Subsurface Portion(g)	Physical Weight(g)	S/R Ratio	Yield Index
Control	25.7	1.736	0.111	1.847	15.7	100
C10%	26.7	1.519	0.101	1.620	15.7	88
C30%	24.8	1.423	0.114	1.537	12.5	82

Table 6 Weights of Root Nodule and Subsurface Portion (Average Weight per Plant, grams in Dry State)

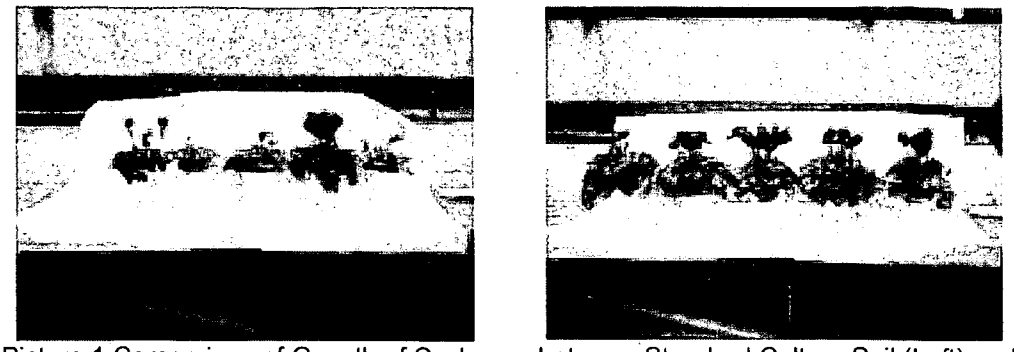
	Weight of Root Nodule (g)	Weight of Subsurface Portion (g)
Control	0.0002	0.349
C10%	0.0044	0.447
C30%	0.0077	0.488

(2) Culture Experiments on Cyclamen

The experiment in the past confirmed that the use of carbonized products in the soil for stock and antirrhinum cultivation resulted in increase in weight of total plant as well as individual organs, compared with pearlite which is used as air permeability agent, and also the proper mixing ratio of carbonized products was 30% to 50%.

The cultivation experiment was carried out on cyclamen that requires a higher cultivation technology. As the result, it found that as far as the growth status before naturalization is concerned, the conventional method produces better results in both the withering ratio and growth rate than the case where the carbonized products is added. It is presumed that since there was no difference in the subsurface growth, the difference in withering ratio and growth ratio is due to the inability of the sprout to break the filler of the carbonized products.

The comparison of the growth both in the conventional soil and the modified soil after naturalization revealed that the number of flowers and flower weight were better than the conventional soil composition when the carbonized product was used as the cultivation medium. The test result confirmed that the carbonized sludge was also suitable for the soil for cyclamen cultivation (Picture1).



Picture 1 Comparison of Growth of Cyclamen between Standard Culture Soil (Left) and Carbonized Product Culture Soil (Right)

Chemical Bonding Form of Heavy Metals

The analysis on heavy metal forms was conducted for zinc, copper, nickel and cadmium employing a successive extraction method. Very little heavy metals in the exchanged state that are likely to elute were detected. The ratio of inorganic and organic coupling state was as small as about 5 to 7 wt %. The most part of heavy metals exist as free oxide and crystallized state which do not elute (Table 7).

Table 7 State of Heavy Metals in Carbonized Sludge

State	Unit	Zinc(Zn)	Copper(Cu)	Cadmium(Cd)	Nickel(Ni)
Exchangeable	mg/kg	1.0	<0.4	<0.2	<1
Metals Combined to Inorganic matter	mg/kg	93.4	53.6	<0.2	4.3
Metals Combined to Organic matter	mg/kg	1.1	<1	<0.5	<2.6
Metals Occluded by Free Oxide	mg/kg	73.3	174	<1	<5.2
In the Crystal lattices	mg/kg	1970	541	<0.5	65.5
Total	mg/kg	2139	769	<0.5	69.8

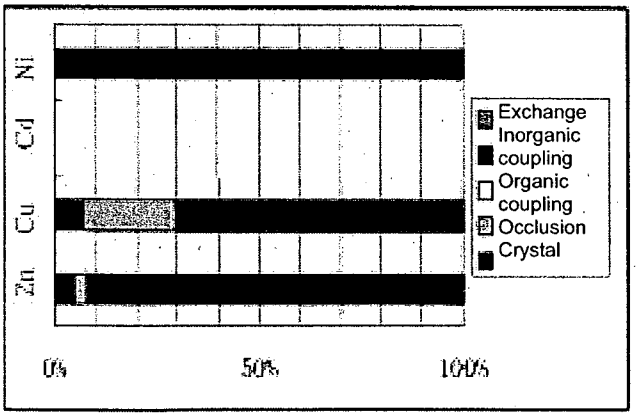


Figure 5 Retaining State of Heavy Metals in Carbonized Products

Note: Since more than 90% of heavy metals are retained in the crystal or occlusion state, the possibility of elution under the natural environment is very low.

2. Application to Deodorization

Since the carbonized product has similar pore volume to that of charcoal, its characteristic to absorb and remove odor ingredient is attracting attention. Since it is excellent ability to absorb hydrogen sulfide, the evaluation test as deodorizer was made in comparison with the activated charcoal. Breakthrough and absorption amount test of hydrogen sulfide was conducted using both the carbonized sludge and the activated charcoal.

The experiment was carried out by using PVC column in which the activated charcoal or the carbonized sludge was filled. Hydrogen sulfide was gone through the column. Concentration of sulfide was measured at the inlet and outlet of column. Thus, the relationship among the concentration of the original odor, the ratio of order removal and the breakthrough time were measured. Tables 8 and 9 show the properties of materials used in the experiment and test condition.

Table 8 Physical Properties as Deodorizer

Carbonized Product	Specific Surface Areas : 10～100m2/g Pore Volume : 0.01～0.1cc/g
Activated Charcoal	True Density : 2.1g/cc Particle Density : 0.75g/cc Filling Density : 400～470g/l Specific Surface Area : 1200m2/g Pore Volume : 0.86cc/g in Granule State

Table 9 Condition for Deodorization Test

Item	Requirements
Superficial Velocity (LV)	0.3m/sec or below
Contact Time (CT)	1.2 sec or above
Layer Thickness	36cm and 72cm
Concentration of Original Odor (H2S)	70, 100ppm

The relationship between contact time and breakthrough time, when the breakthrough point of an absorbing agent is set at the point where the concentration of exhaust gas reaches 5% of the original gas, is shown in Figure 6. The breakthrough time with the hydrogen sulfide of 100ppm concentration and the 2.54 sec. contact time was 60 min. for the activated charcoal and 27 min. for the carbonized sludge, respectively. In the case of 70ppm hydrogen sulfide concentration, the breakthrough time was 57 min. for the charcoal and 39 min. for the carbonized sludge. Namely, the breakthrough time for the carbonized sludge was about 1/2 of the activated charcoal. The filling volume of deodorizer and the total absorption volume of hydrogen sulfide at the breakthrough point of the deodorizer were measured, as shown in Figure 7. It was confirmed that the carbonized products have about 1/2 absorbing ability of the activated charcoal. While the absorption ability of charcoal was 40mg/100g, and that of the carbonized sludge was 20mg/100g. It is generally believed that the pore size distribution of activated charcoal greatly affects its odor absorption ability. Judging from the fact that the carbonized products, having about only 1/10 to 1/100 of specific surface and the pore volume compared with those of the activated charcoal, small amount contaminants such as iron and calcium are probably playing an important role in absorption ability.
In application of the carbonized products at the actual facility such as sludge storage tank, it is revealed that the absorption ability of carbonized sludge was about 1/3 of the commercial activated charcoal. In the future, use of the carbonized products of sludge as deodorizer in sewage treatment facilities etc. can be expected.

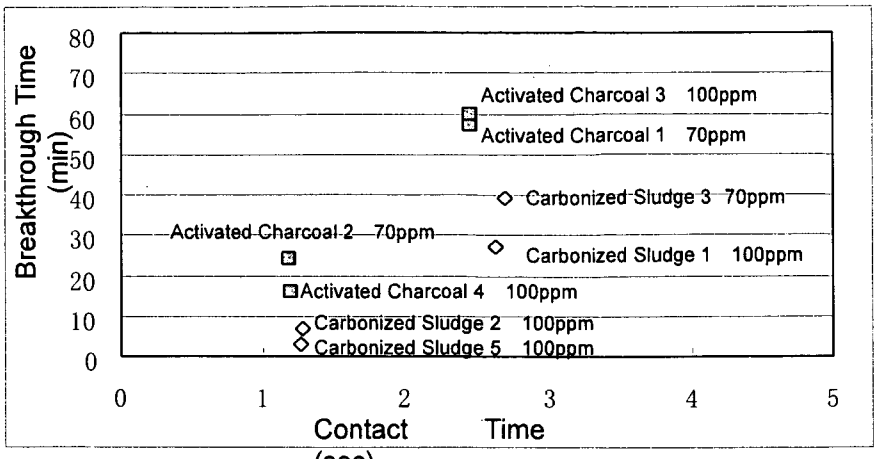


Figure 6 Contact Time with Hydrogen Sulfide and Breakthrough Time

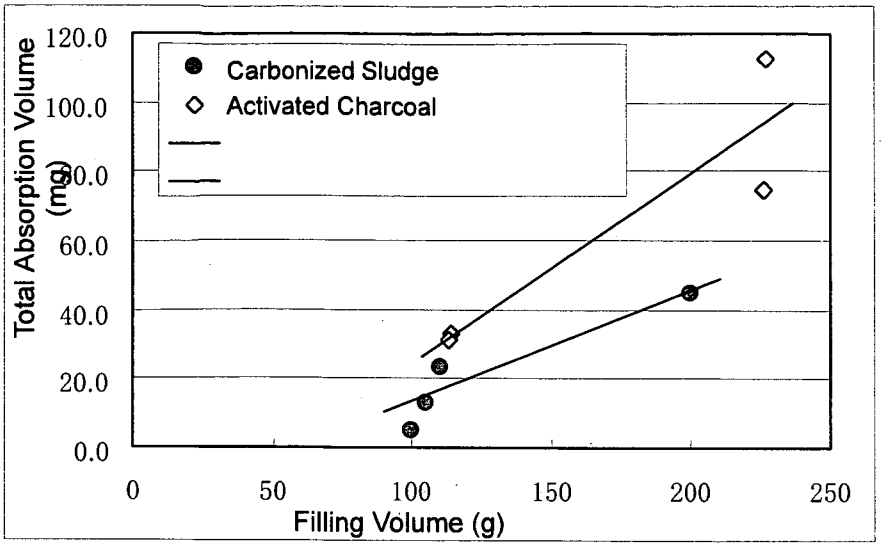


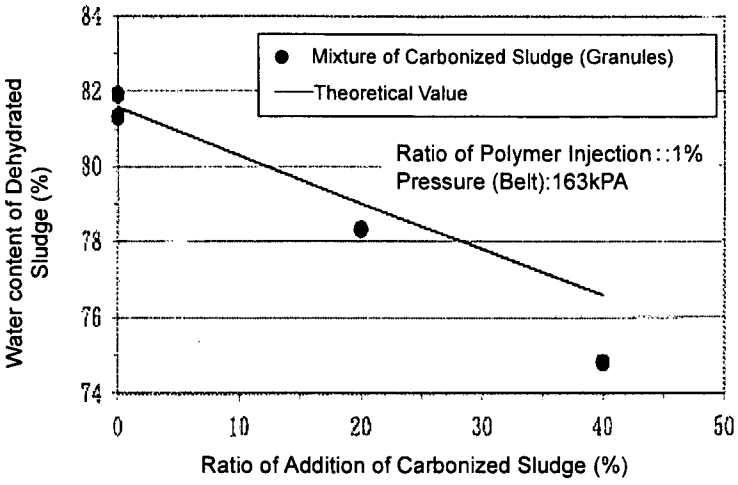
Figure 7 Total Absorption Volume of Hydrogen Sulfide on Activated Charcoal and Carbonized Products

Note: It has been confirmed that the carbonized products have approx. 1/2 to 1/3 of the total absorption volume of the charcoal on the market. They are particularly effective for sulfide gas odor.

3. Application to Dehydration

In the sewage treatment facility, cost reduction is an important item to be solved. In order to decrease the cost, dehydration is one of the key processes. A dehydration process using polymer coagulant and carbonized sludge as dehydrating auxiliaries for filter press already practically operates and gets the satisfactory results. This is the alternative method of ferric chloride-lime dehydration method.

Possibility of application to a belt press dehydrator, a filter press dehydrator and a centrifugal dehydrator is also examined. As equal to or less than the theoretical value water content was obtained with the addition of the carbonized products to the system, the application of the carbonized sludge to these type of dehydrator is also possible. Figure 8 shows the effect of addition of the carbonized product to the filter press dehydration process. Deviation of water content from the theoretical value was about 0.5% in case of addition of carbonized product by 20%, and 2% in addition by 40%. The experiment result suggests that the addition of the carbonized products to the dehydrated sludge as a dehydrating auxiliary has the positive effect and improve the dehydration capability, as result, can reduce the volume of sludge. Further, since the addition of the carbonized product reduces the water contents of the sludge down to 3 to 6%, the carbonized products is considered to have a lot of additional advantages in the after-treatment of dehydrated sludge such as combustion, melting and compost treatment



Note: By adding carbonized products, sludge cakes having a lower moisture percentage than theoretical value by 0.5 to 2% were produced. The carbonized product is presumed to have coagulation effect.

Figure 8 Effect of Addition of Carbonized Products in Belt Press Dehydrator

SAFTY INVESTIGATION

1. Exothermic Characteristic

Like as coal, the carbonized products has the exothermic or auto-ignition characteristic (Self-exothermic characteristic), when it is stored for long period time at a place with poor air permeability and thermal insulation. Since the self-exothermic phenomenon was observed in the storage hopper of carbonized products in the sewage sludge carbonization system, the intensive studies have been made to inspect its characteristics and safety measures. It was found that the sample easily generate heat, has fewer pore volume, low true density and great deal of volatile materials, this product is produced by insufficient carbonization. Accordingly, studies have been made with regard to the relationship between the extent of carbonization (refining ratio), the ratio of hydrogen and carbon (H/C), and the ignition temperature.

The test shows that the carbonized products with low refining ratio has high H/C ratio and active self-exothermic characteristic, and an low ignition temperature, approximately 200 ℃. Based on these facts, it became evident that the refining ratio can be an index of exothermic characteristic.

It has also been found that if calcium and aluminum exist in such forms as lime and aluminum oxide, they are hydrolyzed into calcium hydroxide and aluminum hydroxide, generating heat of hydration by water in the air. However, it has also been confirmed that temperature rise by humidification is relatively small and it will not be directly cause of heat generation and ignition of carbonized products. Further, it is also confirmed that the carbonization does not convert the heavy metal compounds into an unstable or easily

oxidizable form, such as metal or carbide, and that the oxidation of metal compounds have little influence on heat generation of the carbon product.

Table 10 Ignition Temperature of Carbonized Products

	Specific Surface Area (m2/g)	Pore Volume (ml/g)	Ignition Temperature (Activated Charcoal Method)
Sludge Carbonized Product A	31.9	0.0853	327
Sludge Carbonized Product B (With Strong Exothermic Characteristic)	16.2	0.0597	261
Activated Charcoal Made from Coconut Husk	1,000～1,200	0.46	300
Charcoal	50～400		300～400
Coal	13～35	0.2～0.9	400

Note: Carbonized products derived from sewage sludge have different physical properties and ignition temperature depending on sludge conditions. The confirmed lowest ignition temperature is 261 °C. It has been confirmed that they are likely to easily ignite compared with other carbonized products.

Table 11 Relationship between Carbonization Degree and Ignition

Sample	Ignition Temperature(°C)	Refining Ratio	H/C (Ratio of Number of Atoms)
Sewage Sludge Carbonated Product A	323	Below 1	0.142
Sewage Sludge Carbonated Product B	285	2.5	0.275
Sewage Sludge Carbonated Product C	295	3.1	0.27
Sewage Sludge Carbonated Product D	255	3.9	0.358
Sewage Sludge Carbonated Product E	200	8	0.620

Note: There is a correlation between the ignition temperature and the refining ratio, an index of the carbonization degree, and H/C. The lower the carbonization degree (i.e. high refining ratio and H/C value) is, the lower the ignition temperature is.

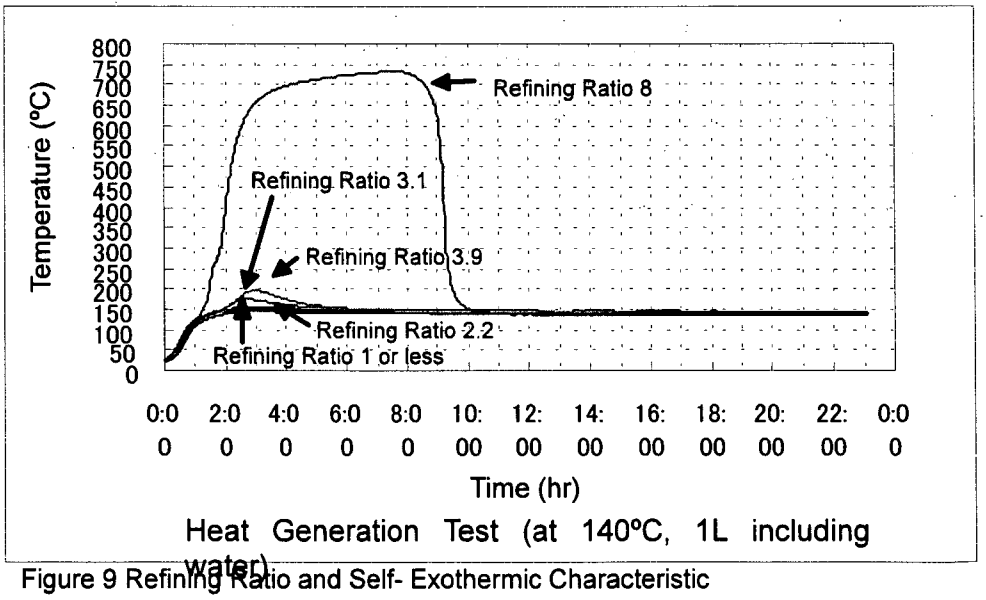


Figure 9 Refining Ratio and Self- Exothermic Characteristic

Note: The temperature of the carbonized product with the refining ratio of 8 considerably rose approximately 2 hours after the self-exothermic test. No temperature rise was found with the products having a refining ratio of 2.2, 1 and below.

2. Control of Self- Exothermic Characteristic

The test results on the self-exothermic characteristic of carbonized products are shown in Figure 9. It has turned out that the carbonized products having the refining ratio of 3.1 and above show the self-exothermic characteristic. The product of the higher refining ratio, i.e. the lower carbonization ratio generates more heat. The experiment on the self-exothermic characteristic was conducted for the carbonized products humidified with water by 30 to 40 % as countermeasure against heat generation. Temperature rise caused by self-exothermic reaction and hydration was suppressed by latent heat of evaporating water. However, at the same time, it was confirmed that the products with extremely insufficient carbonization occasionally show self-exothermic characteristic upon hydration and re-drying. Accordingly, the proper degree of carbonization for control of self-exothermic characteristic, and the stabilization of heat generation by humidification are essential for safe handling of the carbonized products.

CONCLUSION

The sludge treatment technology at the sewage facilities is undergoing a drastic change, from simple treatment to effective utilization of the products. Of various technologies that are being proposed for the effective utilization of sludge, the carbonization technology is the prospective method, because the carbonized products are expected to have effective applications.

When considering introduction of carbonization system, it is required to fully research the effective utilization, market and feasibility of the products. In order to use the sewer sludge effectively from now on, it is important to raise the quality of the products manufactured and that making sewage sludge into materials has the original feature, which changes that it is advantageous, becomes the business called for.

<Description of the refining index>

The refining index is the "t" of the electric resistance 10tΩ/cm. As the carbonization process advances, the electric resistance gets smaller, so does the value of " t" .

From the viewpoint of beneficial application, good carbonized products are within the range of the refining index between 1 to 5. However, from the viewpoint of restraining the clarification, the refining index should be desirably 3 or less.

The ignition temperature is in relation with the refining index, an indicator of carbonization degree and H/C. The lower the carbonization degree is (the higher the values of refining index and H/C are), the lower is the ignition point.

COST MINIMISATION BY DISINTEGRATION - A FULL-SCALE COMPARISON

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ABSTRACT

To optimize anaerobic digestion, different methods of disintegration were investigated at a full-scale plant. Two stirred ball mills, a plant for oxidation with ozone, a lysate centrifuge and an ultrasonic homogenizer were applied.

A positive influence of disintegration on the anaerobic biodegradability could be established with all aggregates. The enhancement of the degree of degradation varied between 7.4 to 26 %. Beside this, laboratory investigations proved that disintegration increases the polymer demand and leads to a lower solid content after dewatering. Higher ammonia concentrations in the process water after dewatering corroborated the results of the anaerobic degradation.

Capital costs for the aggregates, costs for energy, manpower and maintenance can be covered, if specific costs for disposal are high. If the development of sludge treatment costs in future and the current discussion about sludge disposal are taken into account, sewage sludge disintegration can be a suitable technique to minimize costs on waste water treatment plants.

KEYWORDS

Disintegration, economic efficiency, full-scale investigations, improvement of stabilization, lysate centrifugal technique, ozone treatment, stirred ball mills, ultrasonic homogenizer

INTRODUCTION

The main part of costs at waste water treatment plants consists of costs for disposal and energy. Applying disintegration, the reduced sludge quantities will lead to a minimization of disposal costs. Also a minimization of the energy costs by increasing the biogas production and by optimizing biogas utilization is intended.

Sewage sludge disintegration is a stressing of sewage sludge by external forces using mechanical, thermal, chemical or biological methods. With low energy input this treatment changes the floc structure. A higher energy input needed for the disruption of the cell wall results in a solubilization of the organic matter in the sludge. Due to that, disintegration enables an accelerated and an enhanced degradation of organic matter. Extensive research work in half-scale and lab-scale plants has already shown that disintegration is a suitable

method to make organic material from excess sludge available for the degradation in an anaerobic process. Especially at short retention times (< 15 days) an enhanced degradation of organic matter can be achieved. An increase in the degree of degradation of about 10 to 30 % [1] can be attained. The second effect is a change in dewaterability. In most cases a higher polymer demand for an optimal dewatering could be observed [2]. The increased degree of degradation also effects the process water after dewatering, which shows a high concentration of ammonia-nitrogen.

In order to verify the above mentioned results full-scale investigations are necessary. This paper will show results of investigations at a municipal WWTP located in Schermbeck (Lippeverband, Germany) comparing different disintegration aggregates and methods. The application of two different stirred ball mills (disk mill system, annular chamber mill system), a chemical disintegration by partial oxidation with ozone, a lysate centrifuge and an ultrasonic homogeniser were investigated.

METHODS

Disintegration at Schermbeck WWTP

Investigations took place at Schermbeck WWTP which is an activated sludge plant with a capacity of 17,000 PE. The wastewater treatment consists of primary settling followed by biological nitrogen and phosphorous removal. The excess sludge is thickened in a gravity thickener to 25 g/l suspended solids (volatile suspended solids: 17 g/l) before being digested together with the primary sludge in two mesophilic digesters with a retention time of 17-18 days. Daily flow of excess sludge varies from 12 to 30 m^3/d. Flow of primary sludge is about 6 to 10 m^3/d with an average concentration of suspended solids of 27 g/l (volatile suspended solids: 20 g/l). Disintegration of excess sludge takes place in the influent of one digester. Up to now, there have not been enough long-term experiences about the disintegration of sewage sludge. Due to that fact, the disintegration aggregates with the exception of the ultrasonic homogenizer only worked for five days a week. To ensure a continuous effluent from the gravity thickener as well as a continuous influent in the digester, two storage tanks were installed prior to and after the disintegration aggregate. Hydraulic retention times in the storage tank after the disintegration aggregate varied between 1.8 to 4.5 days.

Methods of Sludge Disintegration

Stirred Ball Mills consist of a cylindrical grinding chamber which is almost completely filled with grinding beads. A rotor forces the beads into a rotational movement. The micro-organisms are disintegrated between the beads by shear and pressure forces. For a continuous operation the beads are held back by centrifugal forces and an additional sieve. This kind of mill is called disk mill system and was investigated in Schermbeck (Type LME 50 K, Netzsch Feinmahltechnik GmbH). The motor rating was 37 kW. Circumferential speed of the rotor was set at 15 m/sec. The grinding chamber kept a volume of 52.8 l. About 85 % of the grinding chamber were filled with grinding beads, which were of a different material and diameter (SAZ-balls/600-800 μm and zirkon-sand/150-250 μm).

For the annular chamber mill the grinding chamber is made up of two double cylinders. Separation of the grinding beads is achieved by centrifugal forces alone. A stirred ball mill from the company Draiswerke (Type Cosmo 25), also investigated in Schermbeck, makes use of this method. The motor rating was 30 kW. The grinding chamber was smaller and kept a volume of about 8.5 l. Circumferential speed of the rotor was set at 22 m/sec.

Chemical Disintegration with Ozone: Due to ozone treatment cell walls of micro-organisms are disintegrated and inner cell products can be released. In addition ozone reacts with organic compounds that are less biodegradable, oxidizing them to smaller compounds which are bio-available. In Schermbeck a plant for ozone treatment was made available from the company Wedeco. It consisted of a storage tank for oxygen, an ozone generator (maximum power rating 7.5 kW), and a reaction tank of 6 m^3 volume. A maximum ozone load of 1 kg

O_3/h could be generated. Ozone was inserted by an injector in the reaction tank bypass.

The Lysate-Centrifugal-Technique uses a thickening centrifuge equipped with a disintegration device located at the discharge of the thickened sludge. Tools on the rotor and the stator stress the sludge by shear-forces. Additional energy needed for the disintegration is low. But this results in a very low degree of disintegration. A lysate centrifuge from the company Hiller (Type DECATHICK DT31-422) was investigated for four months. Motor rating was 15 kW. The number of revolutions of the drum was 8500 per minute with a maximum flow of 10 m^3/h. During the research project only the effect of disintegration and not the effect of thickening sludge were to be investigated. For this reason the thickened sludge was diluted again with centrate water. This was the only possibility for comparing the two digesters with similar hydraulic retention times.

Ultrasonic homogenizers consist of three major components. A generator supplies a high-frequent voltage. A ceramic-crystal of piezo-electrical material transforms electrical into mechanical impulses, which are transmitted by a sonotrode into the fluid. Cavitation bubbles are created by alternating overpressure and underpressure. The following implosion of the gas and vapor-filled bubbles leads to high mechanical shear-forces which are apt to disintegrate bacterial cell material [3]. During this research project an ultrasonic homogenizer from the company Sonotronic was applied. It consisted of five sonotrodes (frequency 25 kHz) with a total power rating of 5 kW. Volume of the loop-reactor was about 30 l. Only a partial flow (30 %) of the excess sludge was treated by ultrasound. It was assumed in earlier investigations [4] that even with a low energy input an activation of the bacteria could be achieved. These results were to be verified during this research project.

Program of Investigation

To find optimal operating conditions for the stirred ball mills, pre-investigations were carried out. Different parameters were varied such as sludge flow (450 – 1300 l/h), concentration of suspended solids (5 – 25 g/l SS) and bead diameter (150-250 μm, 600-800μm). The plant for ozone treatment initially ran in batch operation with an increasing ozone dose up to 0.06 g O_3/g SS. The sludge flow of the lysate centrifuge varied between 2.4 and 4.3 m^3/h when the centrifuge was in continuous operation. Investigating the ultrasonic homogenizer, sludge flow was varied between 50 and 450 l/h. The results of the disintegration were quantified by the degree of disintegration. This parameter is determined by the rate of oxygen demand (DD_O) and the COD release (DD_{COD}). Both methods are described elsewhere. [5] [6]

After this period of pre-investigation, each aggregate ran for 2-4 months. To quantify the influence of disintegration on anaerobic digestion the specific gas production related to the input of organic matter and the degree of degradation of the organic matter were determined. For that reason the influent flow of raw sludge was recorded as well as the flow of biogas. The concentration of volatile suspended solids VSS was analyzed daily in the influent and effluent of both digesters.

To quantify influence of disintegration on conditioning and dewatering characteristics which can be observed after digestion, specific resistance to filtration, capillary suction time and polymer demand for an optimum dewatering were estimated in lab-scale investigations. Furthermore a prediction of full-scale dewatering results by thermo-gravimetric determination of the water distribution of sludge was possible. The applied method is described elsewhere [7]. In addition the sludge was dewatered in a pilot filter press. To quantify the pollution level of process water after dewatering, concentrations of COD and ammonia-nitrogen were analyzed.

RESULTS AND DISCUSSION

Energy Consumption

During the operation of both stirred ball mills, the degree of disintegration was estimated by

measuring the oxygen demand DD_O. When applying chemical oxidation with ozone and lysate centrifugal technique, calculation of the degree of disintegration by measuring the COD (DD_{COD}) was the only possible method. Using ozone inhibited the bacteria and overlaid the disintegration and inactivation of the bacteria. In case of applying lysate centrifuge, very low and often negative values were determined when measuring the DD_O. This could be an indication for an activation of the bacteria.

The different disintegration methods can be compared using the degree of disintegration in relation to the specific energy which is shown in the figure below. The specific energy is defined as the energy input related to the treated solid mass.

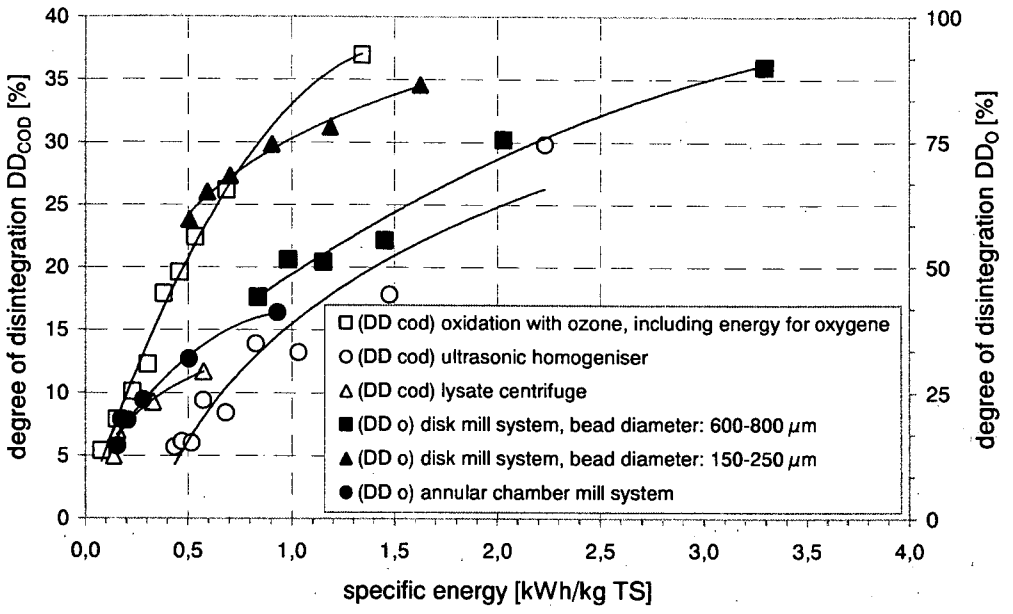

Figure 1: Comparison of different disintegration methods in regard to energy consumption

The annular chamber mill reaches a medium degree of disintegration at a relatively low energy demand. The disk mill uses a higher energy input, due to that, a higher degree of disintegration can be achieved. Using grinding beads with smaller diameters improves efficiency. With chemical oxidation a high degree of disintegration can be achieved, but additional energy for the production of pure oxygen, necessary for generating the ozone, is needed. This has already been considered in the figure above. Energy input of an ultrasonic homogenizer is less effective than the other aggregates. With lysate centrifugal technique an average degree of disintegration of 10 % DD_{COD} could be achieved. During long-term investigations with the stirred ball mills an average degree of disintegration of about 25 % DD_O (annular chamber mill) and 60 % DD_O (disk mill) was obtained. Treatment with ozone resulted in 30 % DD_{COD} mean value. Mean value 17 % DD_{COD} was achieved with the ultrasonic homogenizer.

Operational Behavior

A mechanical pre-treatment was not necessary. Clogging by coarse or fibrous particles was not a problem for any of the aggregates. No abnormal wear at the aggregates was observed. Only a high loss of grinding beads because of wear (disk mill) and the sudden shutdown of the mill (annular chamber mill) occurred. The ozone plant was more difficult to handle because of foaming problems and had several breakdowns. The ultrasonic homogenizer had

at first problems with heat. The sludge flow was not high enough for cooling the sonotrodes. This resulted in several break downs of the sonotrodes. Since an extern cooling system was installed no further problems occurred.

Anaerobic Treatment

When applying the different disintegration aggregates, an increase of the anaerobic biodegradability could be observed in all cases. This effect varied depending on the degree of disintegration. The following table shows the degree of degradation of both digesters, one fed with disintegrated excess sludge and one fed with untreated sludge.

An evident increase of the degree of degradation could be achieved using a stirred ball mill and chemical disintegration with ozone. A lesser effect was observed with lysate centrifuge and ultrasonic homogenizer. Both aggregates achieved a lower degree of disintegration and hence a low increase in the degree of degradation.

Table 1: Influence of disintegration on the degree of degradation

disintegration aggregate / method	degree of degradation with untreated sludge [%]	degree of degradation with disintegrated sludge [%]	relative increase [%]
stirred ball mill (total flow disintegration)	44.0	55.8	26
chemical disintegration with ozone (total flow disintegration)	46.6	55.5	19
lysate centrifugal technique (total flow disintegration)	44.0	47.9	8.8
ultrasonic homogeniser (partial flow disintegration)	48.8	52.4	7.4

In all cases a pre-degradation of the organic dry mass was observed during storage periods in the tank after the disintegration aggregate. The results shown in the table above include this pre-degradation. In this case the biogas produced during this pre-degradation was lost. To achieve an optimum benefit from the application of disintegration, the sludge should not be stored after disintegration.

Dewatering and Conditioning

As a consequence of disintegration the fraction of small particles increases. Due to that, capillary suction time and specific resistance to filtration deteriorate. Parameters, such as the polymer demand and the solid content in the sludge cake after dewatering, which directly influence costs for dewatering and disposal, are of a greater interest.

Table 2: Influence of disintegration on the polymer demand and the solid content after dewatering

disintegration aggregate / method	relative change of polymer demand [%]	change of dewatering result [% TS]	
		thermo-gravimetric measurement	pilot chamber filter press
stirred ball mill (total flow disintegration)	+7.4	+0.2	-2.9
chemical disintegration with ozone (total flow disintegration)	+31	-1.4	-2.7
lysate centrifugal technique (total flow disintegration)	+5.2	-0.7	-2.3
ultrasonic homogeniser (partial flow disintegration)	+8.7	+0.6	-0.7

Table 2 shows that the polymer demand increased slightly due to disintegration. Only disintegration with ozone leads to an evident increase of polymer demand of about 31 %. With thermo-gravimetric measurements hardly any difference in the full dewatering results was predicted, while dewatering with a pilot chamber filter press resulted in a lower solid content in the sludge cake. Only disintegration with the ultrasonic homogenizer did not influence the dewatering result.

The pollution level of process water after dewatering corroborated the results of the anaerobic degradation. TKN in the process water consisted mainly of ammonia-nitrogen, which is, among other substances, a product of protein degradation. Because of disintegration the concentration of ammonia-nitrogen increased, corresponding to the improved degradation of organic matter. During the period of investigation, ammonia concentration increased by about 10 % (stirred ball mill), 17 % (oxidation with ozone), 10 % (lysate centrifuge) and 5 % (ultrasonic homogenizer). Furthermore COD increased about 2 % (ultrasonic homogenizer), 5 % (lysate centrifuge), 17 % (stirred ball mill) and 52 % (oxidation with ozone) due to the solubilization by disintegration and only partial degradation in the digester.

Economic Efficiency

Costs for disintegration were estimated for a model wastewater treatment plant of 100.000 PE [8]. On one hand capital costs for the aggregates including storage tanks, pumps, measurement and control systems have to be covered as well as energy costs for disintegration. This makes up the main part of costs, furthermore costs for manpower, maintenance. Costs for the higher polymer demand and cost for additional aeration resulted from the higher pollution level of sludge process water are negligible.

On the other hand profit of thermal and electrical energy is possible due to the higher gas production resulting from disintegration. But the main part of profit is made by minimizing disposal costs because of a decreased amount of sludge resulting from the higher degree of degradation. Costs for disposal include transport and dewatering. Figure 2 shows the different annual costs as well as the profit due to disintegration.

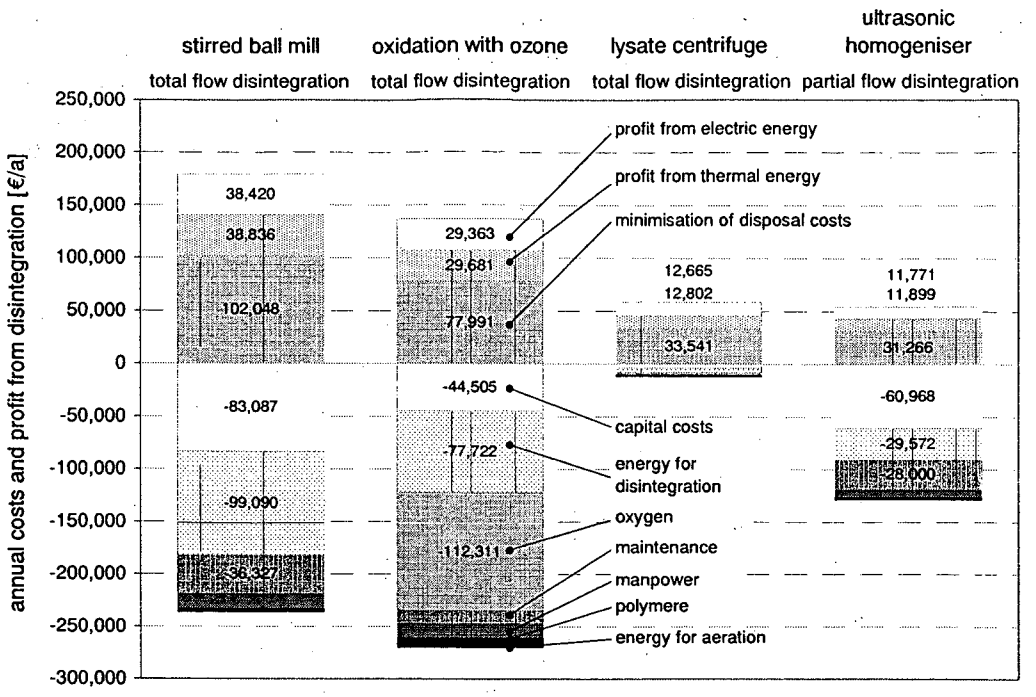

Figure 2: Comparison of costs and profit due to disintegration with specific disposal costs about 400 Euro per Mg digested sludge

Annual costs for disintegration are high, especially for the stirred ball mill and oxidation with ozone. In case of applying chemical oxidation with ozone, additional costs for the oxygen necessary for generating the ozone had to be taken into account. When only a partial flow of the excess sludge is disintegrated, costs decrease . This is evident for the application of the ultrasonic homogenizer. In case of the application of a lysate centrifuge, capital costs are low when a conventional centrifuge is already installed. Due to this, costs result only from upgrading with the lysate equipment. Additional energy resulting from the use of the lysate equipment depends on the dimension of the centrifuge and makes up at maximum 30 % of the energy needed for the operation of a conventional centrifuge.

Most profit can be achieved applying a stirred ball mill and oxidation with ozone. In dependence of the enhancement of the anaerobic biodegradability profit becomes lower when applying an ultrasonic homogenizer or a lysate centrifuge. When calculating the profit from disintegration, it has to be taken into account that profit made from the minimization of disposal costs is influenced by the specific costs for disposal depending on the way of disposal. In this case specific costs of about 400 Euro per Mg dry mass of digested sludge were calculated. Under this circumstances profit is lower than costs for the stirred ball mill, oxidation with ozone and ultrasonic homogenizers. A break-even-point can be achieved if specific costs for disposal are about 625 Euro (stirred ball mill), 1,087 Euro (oxidation with ozone) or 1,350 Euro per Mg dry mass of digested sludge.

The economic efficiency of a disintegration prior to anaerobic digestion is mainly influenced by three factors:

- The achieved improvement of the anaerobic degradation, because this determines the additional gas production and the reduction of the amount of sludge to be disposed of
- The specific disposal costs of the sludge, because they determine most of the cost savings
- The size of the WWTP, because the specific capital costs for the disintegration devices are reduced with increasing size of the WWTP.

By varying these factors, it is possible to calculate the break-even-point for individual circumstances. In Figure 4 such a calculation based on the results obtained in this research work is shown. A volatile solids reduction of 45 % was assumed for the conventional anaerobic process and an energy consumption of 0.5 kWh/kg TS needed for disintegration. Because the capital costs for all disintegration methods are in the same order of magnitude Figure 3 is independent of the method that is used.

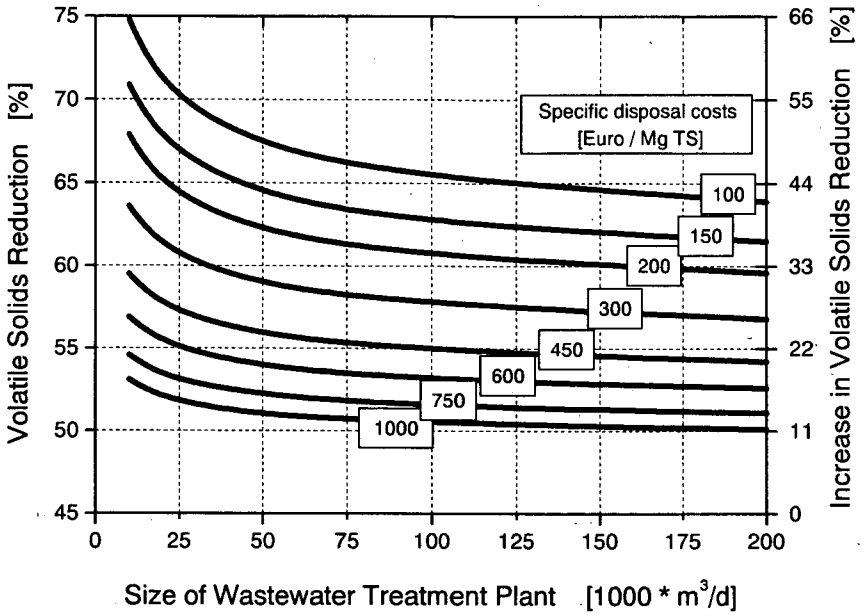

Figure 3: Break even point for the application of disintegration prior to anaerobic digestion [9]

Using these curves, the cost efficiency can be estimated. If for example a WWTP with an influent flow of 50,000 m³/d and specific disposal costs of 300 Euro/Mg can achieve an increase in the volatile solids reduction of more than 30 % (from 45 to more than 58.5 %), the installation of a disintegration device on the plant will save costs.

In this investigation the best results were obtained using the stirred ball mill (see Figure 2), although cost efficiency was not achieved on the basis of the model WWTP of 100,000 PE (20,000 m³/d). With an increase in volatile solids reduction of 26 % and specific disposal costs of 400 Euro/Mg TS it can be derived from Figure 3 that cost efficiency can be reached for WWTP of more than 50,000 m³/d treatment capacity.

CONCLUSIONS

Disintegration of excess sludge is a possible pre-treatment to optimize anaerobic digestion. This has been shown already in various half-scale and lab-scale investigations. To validate these results two stirred ball mills, oxidation with ozone, a lysate centrifuge and an ultrasonic homogenizer were investigated at a full-scale plant in Schermbeck.

In continuous operation a constant quality of disintegrated sludge could be produced with all aggregates. A positive influence of disintegration on the anaerobic biodegradability could be established. The enhancement of the degree of degradation varied between 7.4 % and 26 %. Laboratory investigations validated that disintegration increases the polymer demand and leads to a lower solid content after dewatering. Higher ammonia concentrations in the process water after dewatering corroborated the results of the anaerobic degradation.

A balance of costs and profit from disintegration was estimated. The main part of profit is

made up from the minimization of disposal costs because of a decreased amount of sludge resulting from the higher degree of degradation. The economic efficiency of a disintegration is mainly influenced by the achieved improvement of the anaerobic degradation, the specific disposal costs of the sludge and the size of the WWTP. If the development of costs and the current discussion about sludge disposal is taken into account, sewage sludge disintegration can be a suitable technique for minimizing costs at waste water treatment plants.

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BENEFICIAL USE OF SLUDGE BY MELTING CRYSTALLIZATION FURNACE IN KYOTO CITY

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ABSTRACT

The construction of the sewerage system in Kyoto city started in 1930 and now it has almost been completed in urbanized areas. Approximately 860 thousand m3/day of the wastewater is treated everyday, and around 120 thousand ton/year of the dewatered sludge is generated. Two thirds of the sludge generated is incinerated and the other is melted. The majority of the incinerated ash is landfilled.

As Kyoto city is an inland city, it has faced difficulty in securing landfill sites. In the early stage of the sewerage works, the sludge drying bed had been used for dewatering. But in proportion to the progress of the sewerage service, the generated sludge volume had increased and the reduction of the disposed sludge volume had been pursued by the mechanical dewatering and the incineration. Furthermore, in order to cope with future difficulties for securing the landfill sites and for promoting the beneficial use of the sludge, the melting crystallization facility was constructed.

Through melting crystallization techniques, the melted glass quality slag is converted into crystallized quality which is equal to that of natural stones. In the case of the incinerated sludge, the crystallization by itself is hard due to a shortage of basicity, and hydrated lime is added to the ash. The crystallized slag excels in strength, in heat resistance and in chemical resistance. The masking effect of heavy metals in the slag also is excellent. In the first stage of the facility, the sludge is melted at 1,200 to 1,400℃. The melted slag is cooled spontaneously and after that it is introduced into the crystallization furnace and is crystallized at 1,100℃. The first furnace started operation in 1996, and the second one launched its operation in 2001.

The crystallized slag has a similar quality to that of natural stone and it can be used in various ways such as construction materials. It was named "MIYAKO ISHI", i.e. "the stone of the capital city", in order to encourage people to use it. The Home Page is also used effectively to promote the utilization of the MIYAKO ISHI. The bid for the MIYAKO ISHI commenced in 1999 and around 2,000 tons were sold in 2002. Many products made of MIYAKO ISHI have been manufactured and marketed by tile companies. The main products are outer wall tiles and permeable ceramic blocks. Those products are qualified as Eco-Mark Goods, and are used mainly for the public works. In addition to those usages, it is used for backfilling and mulching material in wastewater treatment plants and the total amount of the crystallized slag is utilized.

KEYWORDS

Beneficial use of sludge, Melting furnace, Crystallized slag

1. INTRODUCTION

Kyoto city is an international cultural and historical city that had been the capital of Japan for more than 1,000 years. It is located in the midway of the Yodo River basin, and has a population of 1.46 million. The water of the Yodo River which receives all of the urban drainage from Kyoto city is used as drinking water by about 11million people who live downstream. The sewerage works of Kyoto city has the duty not only to improve the living environment of the residents in the city, but also to conserve the water quality of the Yodo River.

The sewerage works of Kyoto city launched in 1930. In the mid 1960s, the construction of the sewerage system was defined to be an essential policy of the city. In 1994, the 1200th celebration of the capital city relocation to Kyoto city, the construction of the sewerage system in the urbanized area was almost completed. As of March 2003, the sewered population ratio has come to be over 99%. From now on, efforts will make to improve the quality of the sewerage systems by promoting the advanced treatments and improving the combined sewer systems.

In 2001, the Master Plan of sewerage works for 2025 was published and the basic idea of the sewage works of the city was presented. The main policy of the sludge treatment is fixed on adopting more effective treatment processes and promoting utilization of resources.

As Kyoto city is an inland city and has many important cultural inheritances and sites, the city has faced difficulties in securing sludge landfill sites. Ahead of the other cities, Kyoto city has been dealing with the problem by introducing sludge incineration and proceeding effective use of sludge and incinerated ash. The amount of sludge cake and ash which can be applied to effective uses is limited and a majority of it has to be transported to distant landfill sites. Effective beneficial use of sludge had to be established in order to cope with the future shortage of the disposal sites.

Under those conditions, a melting and crystallization plant was constructed. Sludge is first melted into slag and is crystallized by adjusting the components so as to obtain physical and chemical properties equal to natural stones, for proceeding sludge recycling.

2. OUTLINE OF SEWERAGE WORKS OF KYOTO CITY

2.1 Present state of sludge treatment and disposal

As shown in Figure 1, Kyoto city has six treatment districts, out of which four districts have their own treatment plants as the independent public sewerage systems. Table 1 shows the present condition of sewerage works of Kyoto city. Approximately 860 thousands m^3/day of wastewater is treated in those treatment plants. Around 120 thousands tons/year of dewatered sludge generated is incinerated and converted into around 7,000 tons of ash. And a major part of the ash is landfilled.

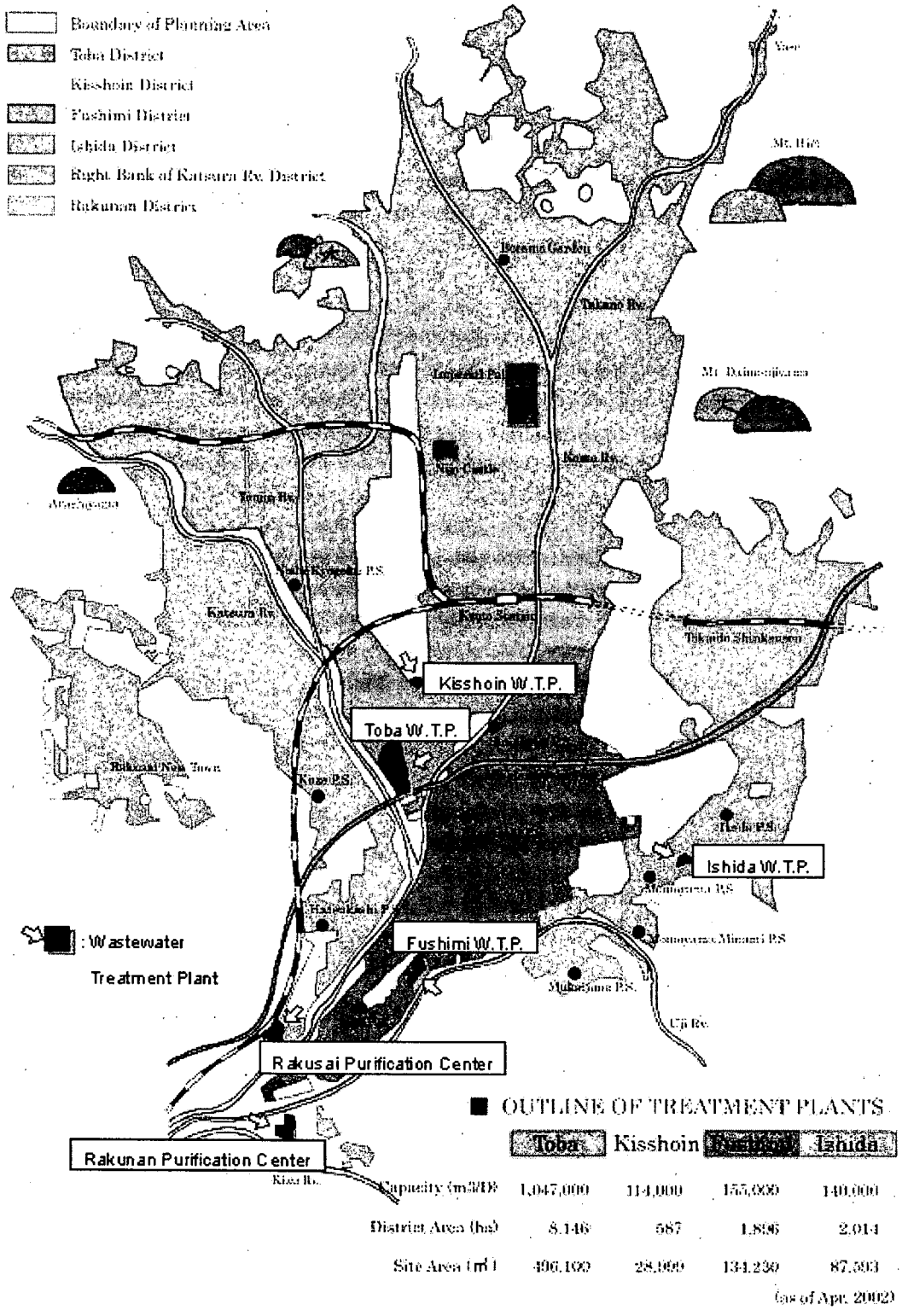

Figure 1 Present condition of sewerage system in Kyoto city

Table 1 Up-to-Date Situation of the Sewerage System in Kyoto City
(as of March 31, 2003)

Total area of Kyoto City		61,022	ha
Urbanized area		15,000	ha
Total population of Kyoto City		1,462,083	
Sewered area		15,074	ha
Sewered population		1,451,000	
Ratio of sewered population		99.2	%
Capacity of treatment plant		1,420,000	m^3/day
Average daily influent wastewater		860,210	m^3/day
Dewatered sludge (total)		125,844	ton/yr
Toba W.T.P		117,560	ton/yr
Ishida W.T.P (Co-combustion with municipal waste)		8,284	ton/yr
Disposal vol. of incinerated ash(total)		10,232	ton/yr
Landfill disposal	:Suzaki	3,152	ton/yr
	:Mizuho	1,753	ton/yr
	:Osaka Bay	2,500	ton/yr
Utilization	:Soil amendments	23	ton/yr
	:Construction material	9	ton/yr
	:Slag use	2,795	ton/yr

Figure 2 shows the sludge treatment system in each plant. The sludge generated from Toba, Kisshoin and Fushimi plant is treated in the Toba plant. From the Kisshoin plant, raw and excess sludge is pumped 1.5km by a pipeline and from the Fushimi plant, dewatered sludge is transported around 4km by truck. In the Ishida treatment plant, dewatered sludge is co-combusted with municipal refuse at adjoining refuse incineration plant.

At the Toba plant, the gravity thickening tanks and the flotation thickening tanks are used. Except a part of the thickened sludge introduced into the digestion tanks, all of the sludge is dewatered by using polymer coagulants. The polymer coagulants are also used in the Fushimi and the Ishida plant. Since 1973, all of the dewatered sludge has been incinerated. Now, the stoker furnaces and the melting furnaces are used for incineration.

A major part of the incinerated ash is trucked to the Mizuho final disposition center, managed by Kyoto Environmental Preservation Public Corporation which is located in around 50km northwest of Kyoto city. It is also trucked to the Amagasaki waste disposal site of the Osaka Bay Phoenix Project, managed by Osaka bay regional offshore environmental improvement center, which is jointly used for waste collected from 195 municipalities along Osaka bay, approximately 45km southwest of Kyoto city.

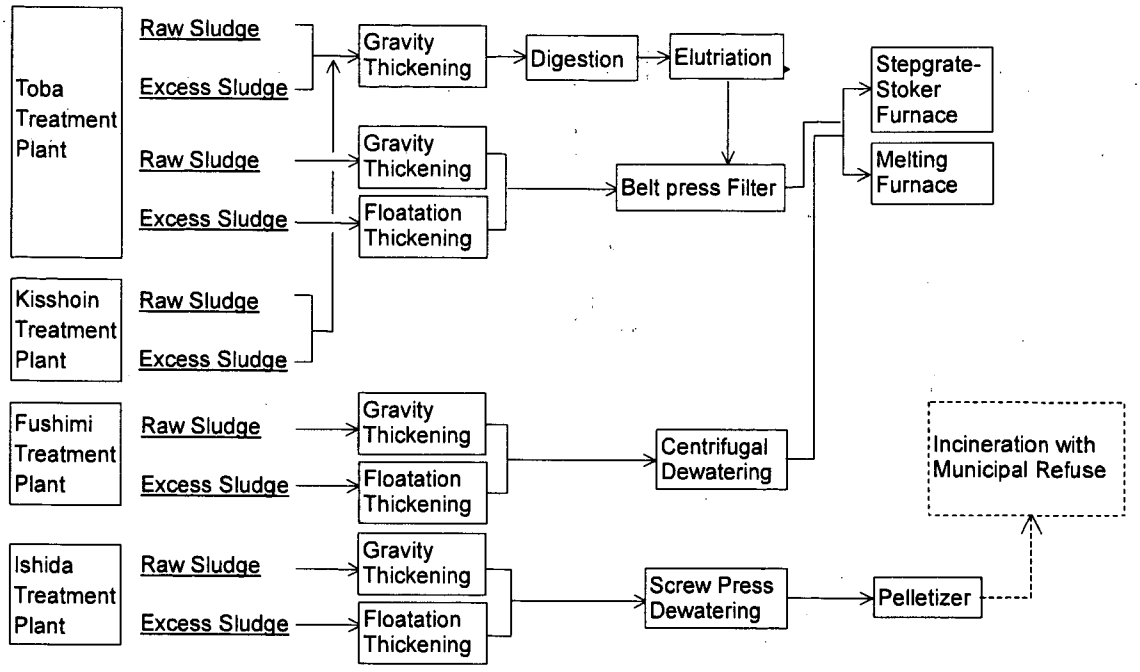

Figure 2 Sludge treatment system of each treatment plant

2.2 Progress of sludge treatment and disposal

Figure 3 shows the amount of wastewater and sludge treatment in Kyoto city. In the dawn of the sewerage works, the "anaerobic digestion-sundrying-landfilling" method was adopted for treating and disposing sludge in the Kisshoin and the Toba treatment plant. In proportion to the expansion of the sewer service area, the amount of generated sludge had increased and in 1965, the vacuum filter system was adopted in the Toba treatment plant for dewatering sludge from both plants. Dewatered sludge was landfilled in the Toba treatment plant. In 1968, a multiple-hearth furnace was constructed and part of the dewatered sludge started to be incinerated. In 1973, the Fushimi treatment plant started operation and all of the dewatered sludge from the three treatment plants was incinerated. In 1986, a stoker type furnace was constructed, and conventionally used inorganic coagulant gave place to organic one to reduce the volume of ash by using belt press filter. As the number of available years for landfilling at the disposal site owned by Kyoto city has been decreasing, landfill at a remote disposal site outside the city was consigned in 1989.

As mentioned before, the city due to the geographical and topographical features had difficulties securing final disposal sites. Therefore, the city needed to take the lead in implementing volume reductions and producing resources out of sludge for beneficial uses such as composting and ash utilization. Studies were conducted with prototypes and application tests were carried out using incinerated ash coagulated by lime in particular as soil amendments for acidified soil, and as raw materials for construction and ceramic. Moreover, utilization has been expanded to crush incinerated ash coagulated by polymer for applications such as blocks or interlocking blocks for pavement in the city walkways as shown in Figure 4.

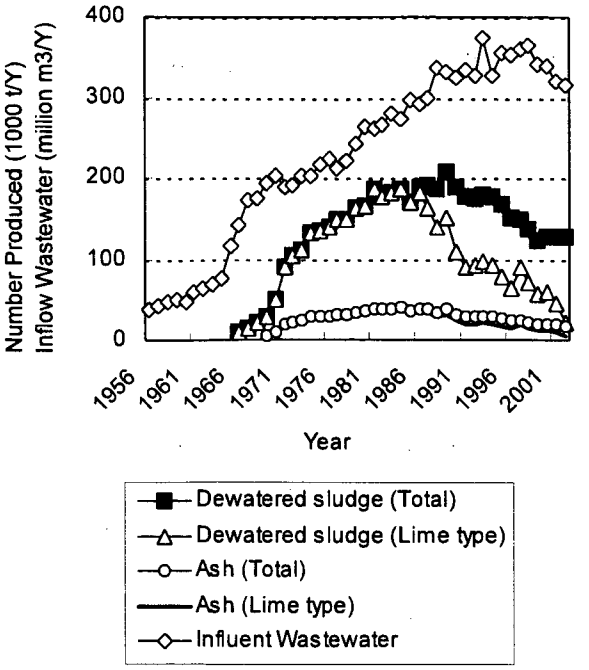

Figure 3 Change of sludge treatment

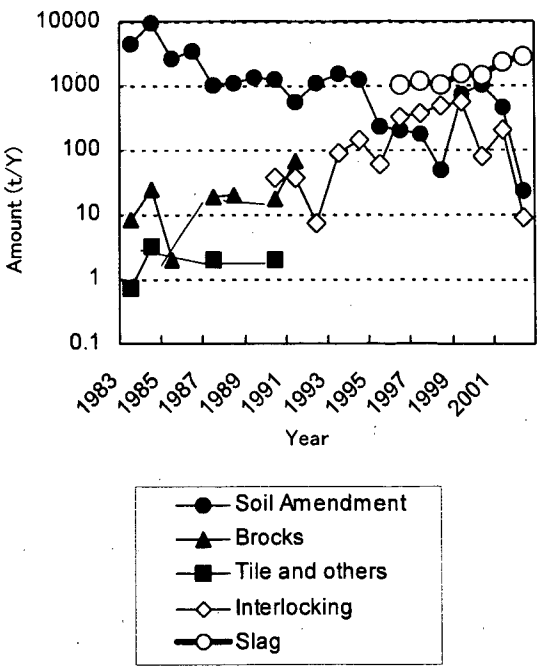

Figure 4 Change of utilization of ash and slag

Soil amendments that were once in demand, gradually decreased due to reductions of agricultural land which resulting from the progress of urbanization. And the use of incinerated ash coagulated by polymer has not been playing an active part in expanding its utilization.

Therefore, the construction of a melting furnace was determined in order to extend active use of the sludge. Melted slag can be used directly as construction materials and immobilize heavy metals. Because glass quality melted slag produced at plants operating in other cities had limited uses, the crystallization facility for improving slag quality was added to the furnace. The 150 tons/day melting and crystallization plant started operation in 1996, and the second one launched its operation in 2001.

3. ADOPTION OF MELTING AND CRYSTALLIZATION PLANT

3.1 Melting and crystallization technology

The technology improves the glass quality of melted slag into a quality equal to natural stones. In the case of sewage sludge, the main inorganic components are SiO_2, Al_2O_3, Fe_2O_3, and P_2O_5, as shown in Table 2. Under the components ratio in the table, the crystallization of slag is hardly progressed due to the shortage of basicity. And as shown in Figure 5, when 10% of limestone is added to ash as a conditioning reagent, the CaO ratio comes to be 25 to 30% and forms anorthite crystals (2 SiO_2-CaO-Al_2O_3).

Table 2 Properties of Dewatered Sludge

Moisture content		wt%	79.3
Solid Combustibles		wt%	74.3
Ash content		wt%	25.7
Calorific value(high)		kJ/kg-ds	16,783
		(kcal/kg-ds)	(4,009)
Ash content (Ash base)	SiO_2	wt%	56.3
	Al_2O_3	wt%	22.7
	CaO	wt%	8.2
	Fe_2O_3	wt%	6.6
	MgO	wt%	2.4
	Na_2O	wt%	1.4
	K_2O	wt%	2.3
	P_2O_5	wt%	1.5
Basicity (CaO/SiO_2)			0.15

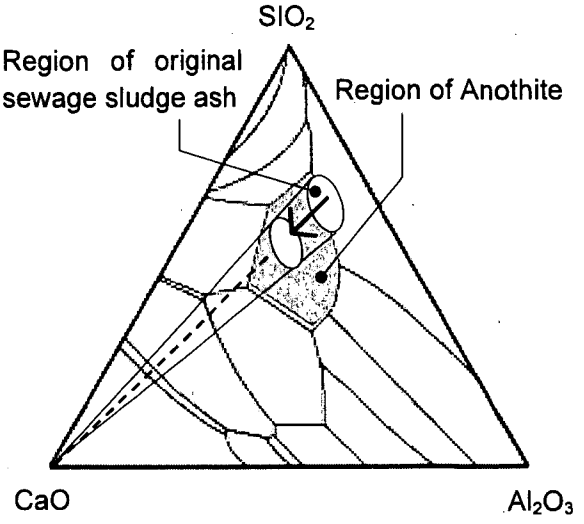

Figure 5 Phase equilibrium diagram of SiO_2-CaO-Al_2O_3

Anorthite exhibits a needle type crystal structure and maintains a somewhat glass quality while holding the characteristics of a crystal. And it shows superior strength, heat and chemical resistance. Generally, crystal core is necessary to precipitate crystal homogeneously in glass quality slag, but in the case of sewage sludge, metal components in the sludge such as iron, etc. play the role of the core.

The physicochemical characteristics of crystallized slag are shown in Table 3. It turns into a luster like obsidian by polishing it and is a good substitute for natural stones in application as aggregates of construction materials.

Table 3 Physico-Chemical Qualities of Crystallized Slag

Items for Measurement		Crystallized Slag	Natural Stone
Compressive strength	kg/cm^2	1,400 ~ 1,670	1,265 ~1,770
Acid resistance [1)]	%	0.1 ~ 0.2	1.1 ~ 1.2
Alkali resistance [2)]	%	0.16 ~ 0.2	0
Water absorption	%	0.0	0.2
Specific gravity	-	2.95 ~ 3.05	2.6 ~ 2.7
Moh's hardness	-	6 ~ 7	7

1) Weight reduction(%) after immersing 15x15x10 samples in 5% H_2SO_4 at 25°C for 250 hours

2) Weight reduction(%) after immersing 15x15x10 samples in 5% NaOH at 25°C for 250 hours

3.2 Outline of the melting and crystallization plant

The plant is composed of the drying facility, the melting facility, the crystallization facility and the flue gas treatment facilities. Figure 6 shows the total flow sheet. Table 4 indicates the outline of the melting and crystallization plant, and the specifications of the main equipment. The vortex melting system incinerates sludge while circulating fine dried sludge particles in the furnace. In order to supply dry solids with a diameter of 1mm or less with solids content of higher than 90%, a circulation type fluidized drying system, which dry and produce fine particles at the same time, is adopted.

Dewatered sludge mixed with fine dried sludge particles is supplied to the fluidized zone. Moisture is evaporated with the heat exchanger installed on the upper part of the dryer, then dried sludge flying out from the dryer is caught in the bag filter and used circularly.

After incinerating the sludge while circulating in the preliminary combustion furnace, the dried sludge is melted in the main melting furnace. As the furnace is inclined 15 degrees, melted slag flows down to the refining furnace spontaneously. Melted slag is kept in the refining furnace for two hours at around 1,400℃ for homogenization, then molded in the molder, cooled and formed into a small clot of glass quality slag. The molder is designed to produce water-cooled slag of less than 5mm, or to produce air-cooled slag of 5-20mm. The cooled slag is reheated in a rotary kiln type crystallization furnace at approximately 1,100℃ to precipitate crystals. Figure 7 is the crystallized slag used of air-cooled and water-cooled slag. Crystallized slag is separated into fine and rough particles with a 5mm screen, and is stored.

In order to heat the crystallization furnace, flue gas from the refining furnace is used. The heat in the flue gas from the melting process is recovered by the air pre-heater and the waste heat boiler. Hazardous matters in the flue gas are removed in the scrubber and dust is removed by the wet electrostatic precipitator. Preheated air is used for combustion in the melting furnace and the recovered steam is used for the dryer.

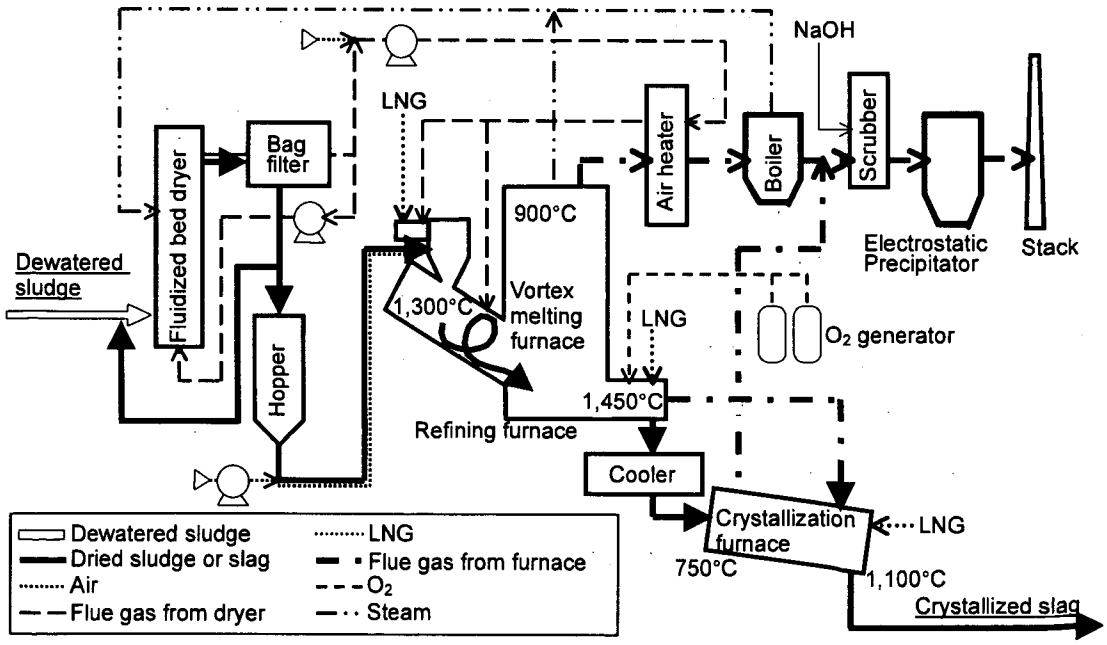

Figure 6 Flow sheet of melting and crystallization plant

Table 4 Specifications for Main Equipment of the Melting and Crystallization Plant

Name of Equipment	No	Spec.(Capacity, Type, etc.)	
1) Dewatered sludge drying facility			
•Fluidized bed dryer	2	Wet cake 5 ton/hr	Circulating Fluidizing Indirect heating
•Dried sludge recovery & distributor	2	540 m^3/hr	Bag filter
•Dried sludge hopper	2	17 m^3	Vertical tubular tank
2) Melting facility			
•Vortex melting furnace	1	Wet cake 150 ton/d	Inclined vortex furnace
•Air preheater	1	540,000 kcal/hr	Radiation heat transfer
•Waste heat boiler	1	Area of heat-transfer 200 m^2	Water tube
3) Crystallization facility			
•Refining furnace	1	1,000 kg/hr	Oxygen enriched burner
•Molding cooler	1	1,000 kg/hr	Water-cooled turntable
•Crystallization furnace	1	1,000 kg/hr	Rotary kiln
•Oxygen generator	1	120 Nm^3/hr	Absorption type
4) Flue gas treatment facility			
•Scrubber	1	18,000 m^3/hr	3 stage spray tower
•Electric precipitator	1	15,000 m^3/hr	Wet electrostatic precipitator

Figure 7 Crystallized slag

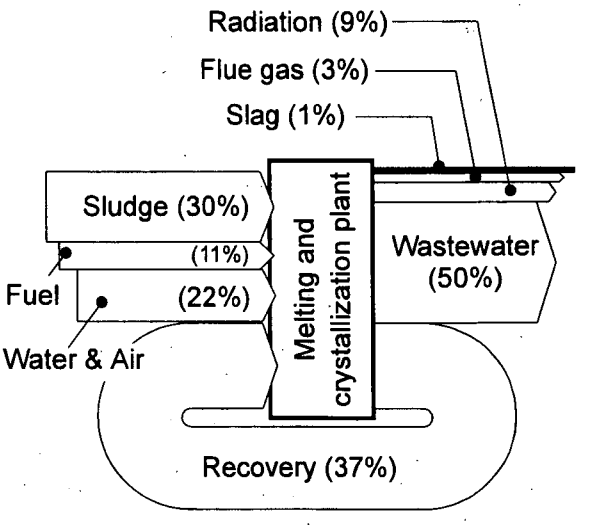

Figure 8 Energy balance

3.3 Energy balance

Figure 8 illustrates the energy balance of the melting crystallization facility. Around 30% of the thermal capacity in the facility is that of the sludge itself. Around 37% of the capacity is recovered and recycled by the steam or by the air preheats. And the thermal capacity required by the supplemental fuel is only 11%.

4. OPERATIONAL CONDITION OF THE MELTING FURNACE

Table 5 shows the operational condition in the 2002 fiscal year. Around 2,800 tons of crystallized slag was produced by dosing around 42,000 tons of sludge cake. The table also shows the utility of the melting furnace.

Figure 9 indicates the maintenance cost of each furnace in 2002. The running costs per dewatered sludge are about 10,000 yen. Because the treatment and disposal cost of the treatment sludge generated from treatment plants is much higher in Japan, the melting furnace is considered effective for reducing dumping site and utilizing resources in the long-term viewpoint.

Table 5 Amount of treated sludge and utility consumption

Amount of treated sludge (Annual)		
Dewatered sludge	42,409	ton
Dried sludge	9,421	ton
Crystallized slag (Generation)	2,795	ton
Utility consumption (Annual)		
LNG	1,672,700	N m^3
Heavy oil A	1,245	kℓ
Caustic soda	288	ton
Lime	767	ton
Drinking water	4,573	m^3
Electric power	10,981,230	kWh

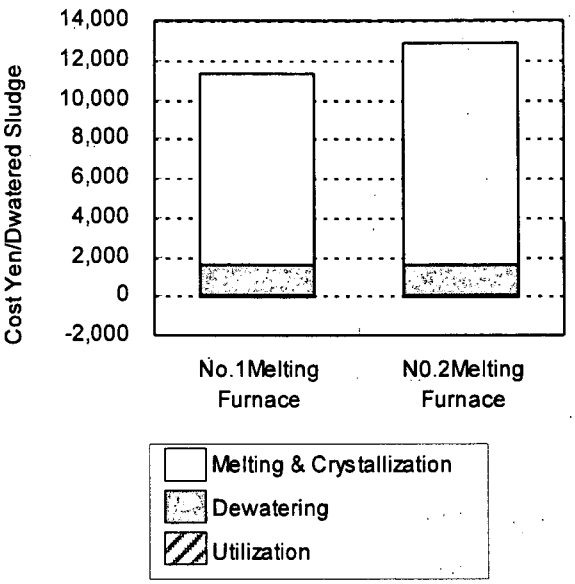

Figure 9 Sludge treatment cost of melting furnace

For the second melting furnace, gas is used as spare fuel in order to reduce exhausted air pollution substances such as carbon dioxide or sulfur oxide, based on the municipal policy that the energy of low greenhouse gas emission is the first priority.

Table 6 shows the exhaust gas composition of the melting furnace. The generation of nitrogen oxides is controlled by the reduction condition in the first combustion chamber which

Table 6 Analysis Result of Flue Gas (2002)

Item		Measured	Standard
Gas vol. Dry gas	Nm^3/hr	29,600	-
Wet gas	Nm^3/hr	28,100	-
Temperature	°C	58	-
Moisture content	Vol.%	4.9	-
CO_2	Vol.%	6.0	-
O_2	Vol.%	13.6	-
CO	Vol.%	<0.1	-
N_2	Vol.%	80.4	-
Dust density	g/Nm^3	0.005	0.08
Sulfur oxide	ppm	0.14	2.34
Nitrogen oxide	ppm	149	250
Hydrogen chloride	mg/Nm^3	3	700
Dioxins	ng-TEQ/m^{3}N	0	0.1

is brought by the gradual supply of the air, and by the complete combustion in the secondary chamber. The concentration of the dioxins is extremely lower than the standard as shown in the table.

5. CHARACTERISTICS AND UTILLIZATION OF THE MELTED SLAG

The crystallized slag has a similar quality to the natural stone and it can be used in various ways such as construction materials. The utilization of the crystallized melted slag has been experimented in various ways.

5.1 The characteristics of melted slag

The inorganic matter contained in the sludge is converted to slag. The main components of the slag are SiO_2, Al_2O_3, Fe_2O_3, P_2O_5, and CaO. The components adjustment is carried out by dosing CaO in order to keep the ratio of SiO_2, Al_2O_3 and CaO in a certain range, so the crystal in the slag composed mainly by those three elements is produced.

This crystal belongs to the Feldspar, which is one of the natural ores, and the crystallized slag has similar characteristics to the natural pebble stone.

(1) Safety of crystallized slag

As the result of the leachate test based on the authorized method by the Ministry of Environment, every experimented value is below the minimum determination limit and satisfies the environmental quality standard for soil.

(2) Physical characteristics

As shown in Table 7, both of crystallized slag larger than 5mm and that of smaller than 5mm satisfies the standard for the aggregate. In the case of the utilization of the melted slag for the asphalt and concrete aggregate and the sub-base course material, the glass-quality slag does not have the required strength and hardness and the usage is restricted. On the other hand, the loss in quantity of crystallized slag is around 15%. This value is almost the same as the natural crushed stone.

Table 7 Aggregate test result of crystallized slag

Item		5mm<			<5mm	
		Result	Standard (for asphalt)	Standard (for concrete)	Result	Standard (for concrete)
specific gravity	(−)	2.94	2.45<	2.5<	2.82	2.5<
water absorption	(%)	0.22	<3.0	<3.0	0.68	<3.0
abrasion loss	(%)	14.8	<30	<40	-	-
soundness test	(%)	0.0	<12	<12	0.2	<10
washing test	(%)	0.053	-	<1.0	0.080	<7.0
unit weight	(kg/ℓ)	1.78	-	1.35<	1.42	1.35<

(3) Distribution of particle size

Figure 10 shows the distribution of particle size of the crystallized slag larger than 5mm and smaller than 5mm. The distribution of the slag larger than 5mm is within the range of the crushed stone No.6. The distribution of the slag smaller than 5mm shows that the ratio of smaller than 2.5mm is lower than that of the range of the crushed sand.

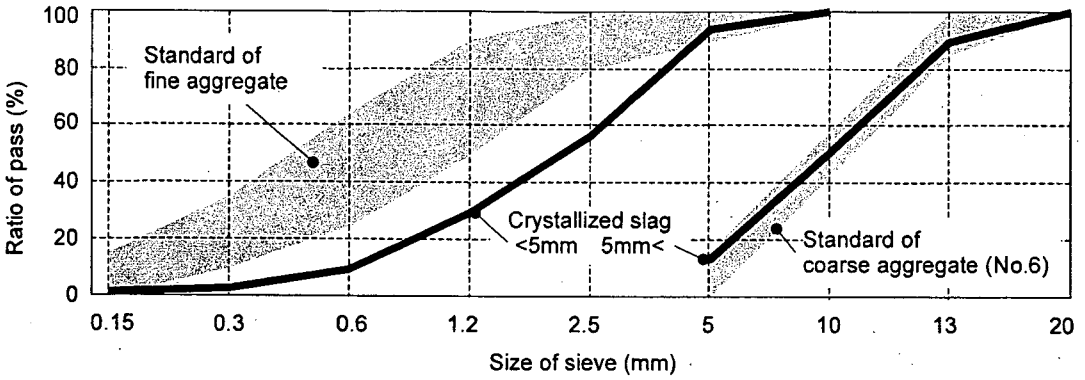

Figure 10 Sieving test result of crystallized slag

5.2 Sales results and utilization examples of the crystallized slag

During the first two years after the launch of operation of the melting-crystallization furnace in 1996, research, experiments and trial producing had been pursued for developing the utilization of the crystallized slag. In those two years, the slag was used experimentally for the sub-base course material and the asphalt aggregate of the inner roads of the Toba treatment plant. Application test of the crystallized slag for the concrete aggregate is now carried out.

As shown in Table 8, the sale of the crystallized slag was commenced in 1999 and 2000 ton of the slag was sold in 2002. The price of the slag is referred to the natural crushed stone and is determined to be 1,100 yen/ton considering the carriage. In 1999 the crystallized slag was named "MIYAKO ISHI", i.e. "stone of the capital city", in order to encourage people to use it. The Home Page is also used effectively to promote the utilization of the "MIYAKO ISHI".

Many products made of the water-cooled "MIYAKO ISHI" are manufactured and marketed by tile companies. The main products are the outer wall tiles and the permeable ceramic blocks. Those products are qualified as Eco-Mark Goods, and are used mainly for the public works by means of the prior supply policy of the "Eco-Mark Goods". The utilization instances of those products are as follows:

Table 8 Selling amount of "MIYAKO ISHI"

Year(Apr.-Mar.) / Application	1999	2000	2001	2002	Remark
Outer wall tile	500				
Permeable ceramic block	500	1,100	1,200	2,000	
Selling amount	1,000	1,100	1,200	2,000	
Production of crystallized slag	1,474	1,445	2,305	2,795	Two plants were operated since 2001

Unit price for selling: 1,100 yen/ton (excl. tax)

(1) Outer wall tile

The quality standard of tile is fixed for each works site, such as standard for outer wall, flooring and inner wall. Among them, the water absorption rate standard for outer walls is the strictest in order to avert tiles from damage by repeated freezing and melting. For material in outer wall tiles, 50% of the crystallized slag, "MIYAKO ISHI" can be mingled. The outer wall tiles mingled with "MIYAKO ISHI" have been used in a total of 15000m^2 in areas such as the Johhana Tunnel of the Tokai-Hokuriku Highway (Figure 11).

(2) Permeable ceramic blocks

Permeable ceramic blocks are used in pavements, parks and open spaces similar to permeable interlocking block made of concrete. As the permeable ceramic blocks are produced in furnaces at high temperatures, it is harder in strength and resists discoloring more than the concrete products. Crushed waste ceramic has been used as the material of the permeable ceramic blocks, though, when the water-cooled crystallized slag smaller than 5mm is used, more than 50% of the material can be alternated with the slag. Up to 2002, permeable ceramic blocks have been used in a total of 7000m^2 in areas including at Dangohzaka Service Area of the Chuou Highway (Figure 12).

In addition to those uses of "MIYAKO ISHI", it is used for backfilling and mulching material in wastewater treatment plants and all the crystallized slag is utilized. The storage facility is now under construction and a stable supply of "MIYAKO ISHI" is promoted.

Figure 11 Construction example of outer wall tile

Figure 12 Construction example of permeable ceramic block

6. CONCLUSIONS

The sludge utilization by producing the crystallized slag performed by the sewerage works bureau was awarded the "Iki-Iki Gesuido Prize", i.e. "vivid sewerage works prize" by the Ministry of Land, Infrastructure and Transport in 2002.

The cost reduction and the quality control have to be carried out by pursuing an efficient operation control. And also, the stable sludge treatment and the crystallized slag production have to be proceeded.

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