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Assessing the Composite Risk of River Contamination –Perspectives, Problems, Methodology

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Synopsis

Surface water from rivers has become more important in Japan over the last few decades. The water demand of households and industry has increased. This study shows how publicly distributed data (ministries, prefecture administrations and others) can be used to improve the assessment of the risk of surface water contamination including triggers and consequences of releases of hazardous substances to surface waters. To achieve this, six analysis methods based on publicly available data are presented in this study, helping to identify sites at risk, possible threats to these sites, gaps in monitoring, accident analysis and combinations of these for proactive measures. Low frequency, high impact events like inundation or accidents are mostly neglected in the current attempts to preserve the water resources and to analyse the risk of contamination. Those cases are also considered in this study.

Keywords: contamination, inundation, river, accident, PRTR, water quality, water basin management, risk analysis, land use

1. Introduction

River water as a source for water supply has become increasingly important in many countries. In Japan, 70% of the drinking and industrial water has its origin in rivers or lakes. The Japanese rivers are characterized by high variance in discharge behavior. Droughts in summer months can lead to economic losses because of shortages in water supply. Because of the importance of surface water resources, water quality is an important issue.

1.1 Composite risk of surface water contamination

Contamination of surface waters is normally caused by multiple sources and triggered by a variety of causes. Sources can be non-point sources like agricultural areas or the run off from sealed urban areas. Point sources are often releases from industrial facilities or sewage waters from households. In addition to the multiple sources, multiple triggers can cause releases of contaminants into the rivers. In addition to continuous releases, point-source type releases can be triggered by accidents or natural hazards. It is also possible that low water during droughts can cause contamination of rivers because of the continuous releases.

To reduce the risk of contamination legislative actions, river basin specific policies and other measures are taken. In Japan many legislative and policy initiatives are described in the environmental law framework (Ministry of Environment, 2004).

The environmental law framework in Japan mainly addresses the risk of contamination by sources releasing continuously into surface water systems. But also low frequency events like accidental or inundation triggered releases should be of concern. A summary of the latter problem can be found in Christou (2000).

1.2 Objective

The objective of this study is to establish an analysis framework to improve the assessment of a water basin with publicly available data using analysis techniques. The analysis should be easily to conduct and should provide decision makers with information for planning measures, in order to prevent releases and contamination, protecting sites handling hazardous chemicals before the impact of threats like inundation or earthquakes and to monitor past measures.
Table 1 lists the 17 considered rivers in and around Nagoya city.

Table 1 Rivers considered in this study.

矢田川	Yatagawa
山崎川	Yamazakigawa
天白川	Tenpakugawa
庄内川	Shonaigawa
新堀川	Shinhorigawa
新川	Shinkawa
瀬戸川	Setogawa
荒子川	Arakogawa
合瀬川	Oosegawa
日光川	Nikkoogawa
中川	Nakagawa
堀川	Horigawa
水野川	Mizunogawa
木曽川	Kisogawa
八田川	Hattagawa
郷瀬川	Goosegawa
五条川	Gojoogawa

1.3 The analysis approach

Based on the available data, the following six analysis methods are introduced, which are helpful for water basin managers to assess the situation.
a) Analysis of the gap between released contaminants and monitored within environmental monitoring programs.
b) Low water risk – where and when is the occurrence of contamination due to low water events probable considering releases by chemical facilities.
c) Flood-inundation analysis – what is the frequency that an identified site handling hazardous substances is inundated
d) Flood-Inundation analysis – which sites handling hazardous substances can be considered for real time protection measures with mobile dam systems.
e) Release analysis – the release characteristic is analysed for the whole catchment, with a focus on the superposition of releases.
f) Temporal-spatial analysis – the effectiveness of policies and regional impacts of policies which can be analysed using statistical-spatial analysis.

2. Context of the analysis

The analysis methods address the following key questions:

a) Which sites constitute a contamination threat, because of the release or handling of contaminants?
b) What kind of threats to the considered facilities/sites exist (accident, flooding, drought, site specific characteristics, like the location in a flood plain)?
c) What is the probability and probable volume of the released contaminant?

3. Data

Table 2 gives an overview of the publicly available data. The combination of different sources allows answering questions according to the established context in the introduction.

Table 2 Data used in this study:

Data	Source
Pollutant Release and Transfer Register (PRTR)	Ministry of Environment
Environmental monitoring data of the river quality	Environmental office, Aichi Prefecture
Hydrographs	Environmental office, Aichi Prefecture
Inundation scenarios	Aichi Prefecture and simulation after Zhang et al. (2003)
Geo-data of infrastructure	Commercial geodata
Major accident data base MARS	Joint Research Center of the EC, Ispra

An important part of this approach is the recently published Japanese Pollutant Release and Transfer Register (PRTR).
The Japanese PRTR is a database tracking chemical use, transfer and releases. A PRTR records chemical specific and standardised data on emissions of hazardous substances to air, water and land (including off-site disposal) from polluting industrial facilities (private, municipal or state).
The PRTR was established for active and regular public dissemination to local communities, industrial managers, government policy makers, and investors. PRTR-databases exist in many countries (e.g. Japan

since 2003, Netherlands, 1974; United Kingdom, 1990; USA, 1987). The PRTR-database set up in Japan includes information about the handled, stored and released hazardous chemicals in facilities, classified according to industrial categories. It also considers 354 so-called “class one chemicals”, which are supposed to have a hazardous effect on human health. The database gives information about measured or estimated yearly release volumes for each designated chemical into surface waters, soil or the air for sites which handle more than 5 tons of a substance within a year and for companies with more than 20 employees. In case no exact information of the release amount of a chemical is available the release is estimated by given formulas for different categories of industry considering the industrial processes. The Pollutant Release and Transfer Register lists all facilities in Japan, which are dealing with one of the 354 chemical substances, listed in the so-called first class list in the Appendix of the Japanese PRTR-law. The database also includes the amount of each pollutant, which is released into rivers. For this study the addresses of each facility were geocoded with the geocoding tool of the Center of Spatial Information Science, Tokyo-University.

Seventeen years of environmental monitoring data for the considered 38 stations along the 18 considered rivers in Nagoya area (table 1, figure 1) were taken from the yearbooks of the environmental office of Aichi Prefecture Administration. Hydrographs are partly provided from the Environmental office of Aichi Prefecture. The hydrograph data consider monthly discharge measurements over the 17 years for which the monitoring program exists.

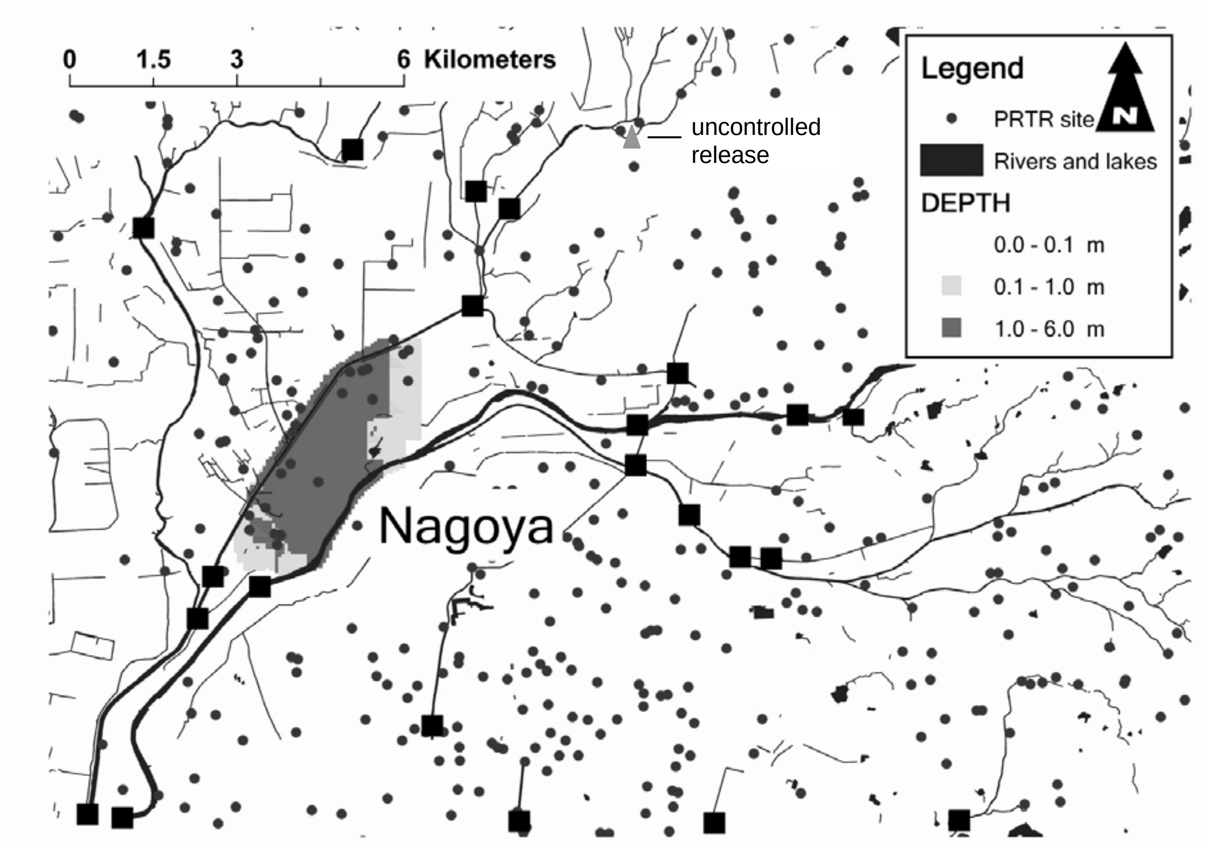

Fig 1 The black symbols mark the monitoring station network in the northern part of Nagoya area. In total 38 stations are sampled. The gray triangle marks an uncontrolled release discovered during a field trip. The inundated area is located between Shinkawa and Shonaigawa.

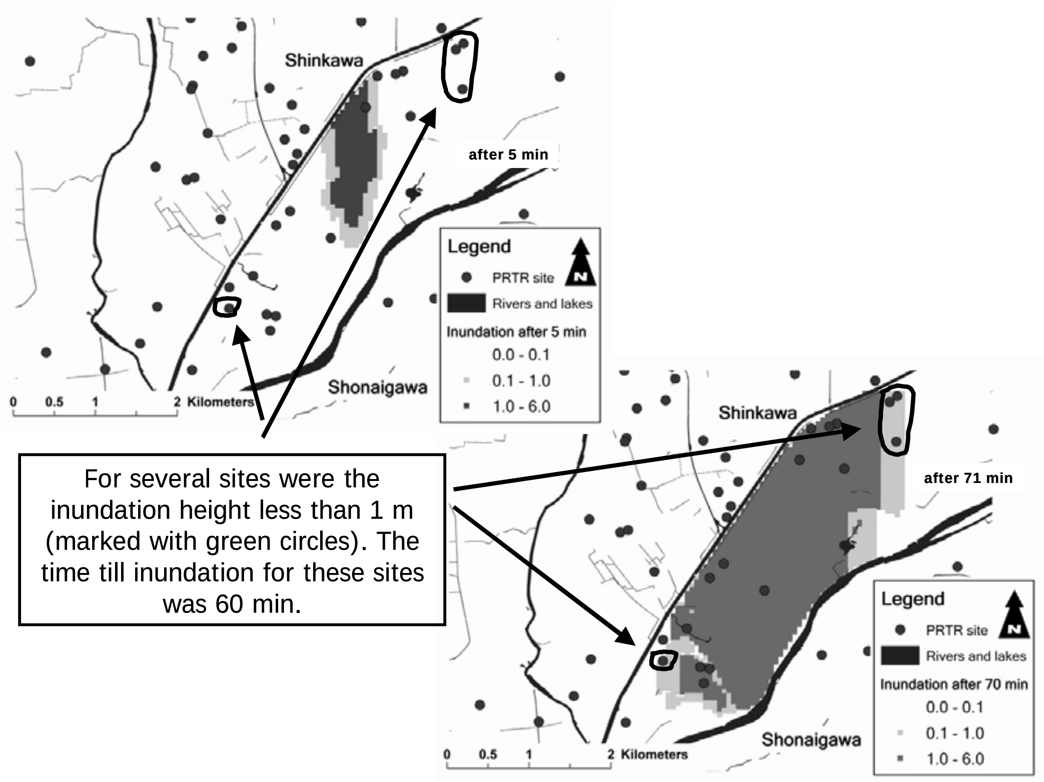

Fig 2 shows inundation scenarios for the break of the river embankment at Shinkawa in September 2000 after 5 minutes and after 70 minutes, when the maximum inundation was reached. Based on probable inundation scenarios protection measures could be planned. Based on real-time inundation calculation task forces can be coordinated for building up modern mobile protection measures, like mobile dam systems or for other security measures. The inundation scenario was adapted after Zhang et al. (2003).

A software tool was developed by the administration of Aichi Prefecture, which gives the frequencies and heights of inundations within the Prefecture. Also flow velocities and breaks of river embankments are considered in this tool.

Additional threats, not including continuous releases or accidental releases, may occur if facilities are flooded and chemicals are not stored in an appropriate way. Such accidental releases are described in Christou (2000).

For additional insights, accidental release data were also included in the discussion. Because no adequate data exist for Japan the database MARS of the EC was used, listing information of over 300 major accidents in the countries of the European Union from the years 1980 to 2003. The MARS accident data base published by the Joint Research Center of the EC, Ispra illustrates differences in accidental releases by industry type.

An example for an inundation event in Nagoya area is the Tokai flood in the September 2000, where several parts of the city were inundated, including facilities dealing with class one chemicals after the Japanese PRTR-law. Figure 2 shows the inundation scenarios after the heavy rainfalls during the Typhoon Nr. 14 in September 2000 in Nagoya for the area between the rivers Shinkawa and Shonaigawa.

The reconstructed inundation scenario was adapted from Zhang et al. (2003). The floodplain between these two rivers was inundated after a break of the river embankment at Shinkawa. The geography of the region makes a future flooding of areas with facilities listed in the PRTR-data base highly probable. For this reason inundation scenarios should be included into a comprehensive analysis. The region is located in the Nobi floodplain, and is partially below the river level due to land subsidence in the last decades (Yamamoto, 1984).

4. Analysis methods and Results

Based on the available data (table 2) an analysis can be conducted to give answers to the three basic questions, established in the context in the introduction. Six methods are now presented: they provide answers to the established context by combining the data sources.

Table 3 Gap analysis between monitored and released hazardous chemicals into the Shinkawa in Aichi Prefecture. The table shows the top ten pollutants released into the Shinkawa and the yearly volume by all sites listed in the PRTR. The field No. classifies the number the chemical substance, given by the Japanese PRTR-law. Only 20 of the released chemicals, released into the 18 rivers and reported by the PRTR, are monitored within the environmental monitoring program. The environmental monitoring program of Aichi Prefecture hasn't changed since 17 years. In total 50 hazardous substances are released in into the rivers in Nagoya area without being monitored, more over, for 40 hazardous chemicals no guideline values are specified by the government or even by the WHO (WHO, 2003).

No	Chemical Substances	Guideline value WHO in mg/l	Guideline value Japan in mg/l	Monitored in Shinkawa	Sum of releases into Shinkawa in kg/a
43	ethylene glycol				5741
304	boron and its compounds	0.5	1		5074
307	poly(oxyethylene) alkyl ether (alkyl C=12-15)				2400
283	hydrogen fluoride and its water-soluble salts	0.05			2224
1	zinc compounds (water-soluble)			**x**	1533
311	manganese and its compounds	0.5			531
309	poly(oxyethylene) nonylphenyl ether				520
232	nickel compounds				185
63	xylene	0.5	0.4		168
207	copper salts (water-soluble, except complex salts)			**x**	140

4.1 Gap analysis: Difference between released and monitored chemical substances and identification of missing guideline values

A gap analysis between released and monitored chemicals in the river can be conducted based on the introduced data. This analysis helps to redesign the environmental monitoring programs considering the reported released hazardous chemicals into each single river system. Table 3 presents a summary of the top ten released chemicals into one of the 17 rivers in Nagoya area.

4.2 Exists a risk of pollution due to low water events?

Considering continuous releases reported by the PRTR-system, the hydrographs of rivers can be used to evaluate whether exceeding guideline values due to low water events is probable. A guideline value of 1 µg /a would be exceeded if more than 31.5 ton/a are released into a river and its discharge is below 1 m^3/s. The analysis of the hydrographs for the 17 rivers shows that this is not probable because the reported release volumes are similar to the example Shinkawa and below 31.5 t/a, while the guideline values are much higher than the expected resulting concentration in the rivers. More importantly, it is improbable that rivers with high release volumes of chemicals fall below 1 m^3/s (figure 3).

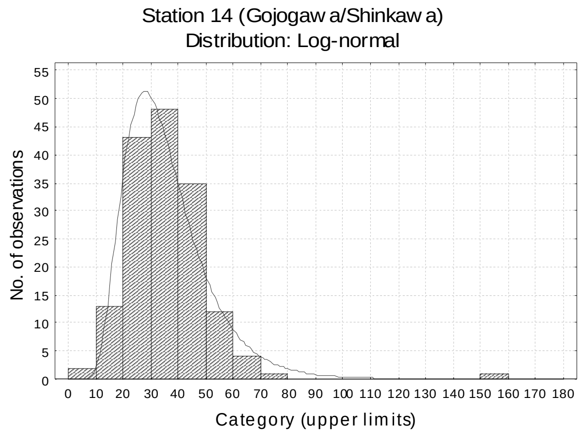

Fig. 3 Distribution of discharges in m^3/s for the station 14 in Aichi Prefecture. The lowest observation was 4.87 m^3/s, the highest 157 m^3/s.

4.3 Probability that a side is inundated

The probability of inundation can be estimated using inundation scenarios based on the meteorological data. The Aichi Prefecture in which the city of Nagoya is located provides, since 2003, a software tool with inundation scenarios and frequencies of inundation. A realistic case for a typical inundation in the case of the break of the river embankment at Shinkawa in September 2000 during the Tokai flood is displayed in figure 2. The river embankment broke on a length of 100 m. Within 70 minutes the displayed area in figure 2 was inundated. In this case 16 facilities, which have to report to the Japanese PRTR, were inundated. 4 of the 16 sites were inundated after one hour with an inundation height less than 1 m. The risk of inundation is useful for planning measures to prevent releases related to the inundation. The Software tool delivered by Aichi Prefecture allows determining the inundation probabilities for each PRTR-site and the expected water height. This knowledge can be crucial to prepare actions in the site after a warning.

4.4 Preparation time for real-time protection measures in case of inundation

In the case shown in figure 2 four facilities were inundated after more than an hour with an inundation height less than a meter. If it is possible to warn such facilities early enough, employees in the facilities can carry out actions to prepare sites for the inundation. This can include shutting down activities or preparing stored chemicals for the inundation event. Because of recently available mobile dam systems to protect a site as long as the inundation height is less than a meter, it is also possible to focus local resources coordinated by administration or the disaster control center. This needs a reliable warning system with appropriate information such as the time until inundation, inundation height and educated resources to deal with this problem. The analysis may identify sites for which such actions are meaningful and focus efforts to educate staff or to inform disaster forces about the sites to include the knowledge into their preparation for future events. A useful technique for distributing real-time data to task forces was developed by Ushiyama & Takra (2002) using the widely used I-mode technique in Japan. It is capable to give online information to users on mobile phones, displaying e.g. maps generated for mobile phone displays.

4.5 Accident analysis: probability of a release and volume of release

Accident analysis can provide administration to assess the vulnerability of a single facility due to accidents. It can be expected that in the future for single countries accident data-bases are available. Also in Japan, there are recent efforts to collect accident data. The experience from the MARS data base shows that the probability of a major accident with a release to the water environment is different for each industry type (table 4). Such knowledge can be used for a first assessment of the risk of an uncontrolled release to the water environment and to take out measures.

Table 4 Sum of reported major accidents to the MARS-database in the EU (years 1980-2002) including the number of those where water was contaminated.

Industry type	**Total Nr.**	**Water conta-minated**	**Ratio**
General chemicals manufacture	**168**	**10**	0.06
Wholesale and retail storage and distribution	**51**	**8**	0.16
Pesticides, pharmaceuticals, other fine chemicals	**41**	**7**	0.17
Petrochemical, refining, processing	**87**	**5**	0.06
Food and drink	30	4	0.13
- not known / not applicable -	4	3	0.75
Paper manufacture, printing, publishing	13	3	0.23
Waste treatment, disposal	13	3	0.23
Agriculture	9	2	0.22
Handling and transportation centres (ports, airports, lorry parks, marshalling yards, etc.)	7	2	0.29
Metal refining and processing (includes foundries, electrochemical refining, plating, etc.)	35	2	0.06
Plastics and rubber manufacture	24	1	0.04
Textiles, clothing and footwear	2	1	0.50
- other -	15	0	0.00
Building and works of engineering construction	1	0	0.00
Ceramics (bricks, pottery, glass, cement, plaster)	2	0	0.00
Electronics and electrical engineering	1	0	0.00
Fairgrounds/amusements	5	0	0.00
General engineering, manufacturing and assembly	1	0	0.00
Power supply and distribution (electric, gas, etc.)	12	0	0.00
Timber and furniture	3	0	0.00

4.6 Temporal spatial analysis: effectiveness of policies and analysis of regional patterns

For the design of new policies it is useful to know if past policies were effective. An appropriate method to analyse if past regulations like the Japanese Law for the protection of the environment (effective since 1994) had an effect on the considered river basin is the analysis of parameters like the BOD (biological oxygen demand). If available, also other parameters with long time series can be considered. Figure 4 shows the seasonal decomposed time series of the monthly BOD-measurements of a station at Shinkawa. It was possible to establish a significant (2, 1, 3) ARIMA-intervention model for this time series, assuming a decreasing gradual permanent effect. A temporal-spatial analysis displaying the spatial patterns of all included monitoring stations can be useful to identify regions where policies had a significant impact. An overview of the station network in North Nagoya is given in Figure 1.

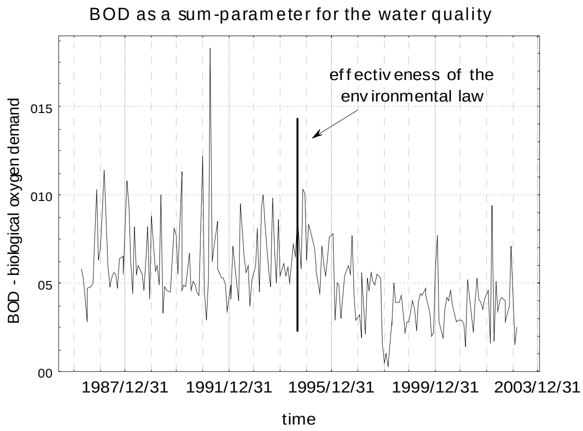

Fig. 4 Change in the long term water quality since the effectiveness of the environmental law in mid of 1994.

5. Discussion

The disadvantage of the existing environmental monitoring programs is that only a limited number of substances is measured (e.g. in Japan, table 3). From this it can be concluded that a contamination can be diagnosed only for measured substances. For many dangerous substances it is not known if they exist in a river or not. This knowledge gap leaves open the question about whether these unmeasured chemicals constitute a risk to the environment or the health of human beings. Every year, new chemicals are discovered and often no information is available as to whether and if they posses a risk to the environment or health of humans. An example of recently identified chemicals in rivers, genotoxic substances, is given in Watanabe et al. (2001). The identified substances in rivers of Kyoto and Nagoya Prefecture, Japan, were PBTA-type substances. These chemicals are possibly related to the textile industry and wastewater treatments. These newly identified substances are not included in the Japanese list of dangerous first class chemicals.

The PRTR-registers, which are established in several countries (e.g. in Japan and Netherlands) or will be established (like in Germany in 2004) give on the one hand a new possibility to assess the risk, on the other hand, they also reveal the weakness in the given information to the public. How can the risk of a substance be assessed if no established threshold values are defined or worse the effect on the system is not known?

The mentioned gaps in knowledge (considering data availability) leave the open question, how the risk through these chemicals can be assessed, especially if the effect on health and environment are not known. Recent developments, like REACH initiative (REACH: Registration, Evaluation and Authorisation of CHemicals) of the EU, where within the next years the produced chemicals should be evaluated on their risk to human health and the environment.

In addition to the continuously emitted chemical substances, the risk due to so called incidents or accidental releases into river systems should be considered. Single low frequency high volume releases into surface waters, like the 1986 Sandoz incident, increase the complexity in the evaluation of the risk for a river system. But the probability of their occurrence makes it necessary to include accidental releases too. This is especially the case for locations like in Nagoya area, where large parts of the sites are located in floodplains and an additional triggering of releases by inundation is highly probable.

Photo 1 Uncontrolled release from a sewerage plant, causing an oily film on the surface, while kids were playing at the water.

A study of Fushimi et al. (2000) analysing the theoretical air pollution of NOx and benzene for Kawasaki City, based on data of a PRTR-pilot project in the year 1998 shows that the air pollution for benzene based on the reported PRTR-data were underestimated by 94 %, the underestimation for NOx was more than 70 %. Considering the difficulties within the calculation of air pollution (e.g. weather conditions, inter region effects) one of the main causes was assigned to the emission data reported to the PRTR pilot project. The experience from this strong underestimation in the study suggests that also the reported emission data for effluents to rivers are not complete and that calculated expected minimum concentrations for the rivers are also too low.

During field research in the considered area, an uncontrolled release on November 16th 2003 upstream of Machiai-bridge, from a sewage plant causing an oily film on the water surface for several kilometers, was discovered (Figure 1; Photo 1 and 2).

To prevent those releases measurements should be taken. A suitable tool for identifying and assessing those facilities the here presented tools may be helpful.

Photo 2 The oily film caused by an uncontrolled release.

6. Conclusion

As a recent study (AWI, 2003) showed how aquatic ecosystems react within several weeks to contaminants transported by rivers. In the shown case the origin of the contaminants were mainly non-point sources (contaminated areas). Major accidents like those reported in the MARS data base can also influence the river quality for several hundred kilometers within the river and can lead to a reduction in the water supply for the population. In conclusion it is important to note that low frequency high impact events should be considered in the risk assessment for water catchments and in the water management plans for a long-term development strategy.

How the risk due to low frequency contamination and their impact can be analyzed was shown, presenting a number of valuable and timely analysis methods. The gained knowledge can be included into decision support models for the development of land use and future policies considering environmental monitoring and effluent standards for facilities dealing with chemicals. Obviously further research is needed for developing efficient risk assessment models. It can be expected that future data availability will support such efforts.

Risk assessment and public information of the results leads to increased social dialogue. Science should contribute to these ongoing processes by the reevaluation of measures, and the implementation of safety standards.

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References

Alfred Wegener Institut (2003): Spätfolgen der Elbeflut, Press release from the 21st of March, 2003.

Christou, M.D. (2000): Substances dangerous for the environment in the context of the council directive 96/82/ec, Report by Technical Working Group 7 of the Joint Research Centre, Ispra, pp. 43

Fushimi, A., Kajihara, H. and Yoshida, K. (2000): Approach to Risk Assessment for Air Pollutants Using PRTR Date and Atmospheric Dispersion Model, Proceedings of the 3rd International Workshop on Risk Evaluation and Management of Chemicals. pp.13.

Kirchsteiger, C. (1999): On the use of probabilistic and deterministic methods in risk analysis, Journal of Loss Prevention in the Process Industries 12/5, 399-419.

Ministry of Environment (2001): Water Environment Management in Japan, pp. 44.

Ministry of Environment (2004): Laws and Regulations in Japan, Internet-Page: http://www.env.go.jp/en/lar/.

Ushiyama, M., and Takra, K. (2002): An internet-based real-time heavy rainfall display system, J. Natural Disaster Science, 4/2, 43-49.

Watanabe, T., Nukaya, H., Terao, Y., Takahashi, Y., Tada, A., Takamura, T., Sawanishi, H, Ohe, T., Hirayama, T., Sugimura, T. and Wakabayashi, K. (2001): Synthesis of 2-phenylbenzotriazole-type mutagens, PBTA-5 and PBTA-6, and their detection in river water from Japan, Mutation Research/Genetic Toxicology and Environ. Mutagenesis, 498/1-2, 107-115.

WHO (2003): Guidelines for Drinking Water Quality, WHO, pp. 222.

Yamamoto, S. (1984): Case history No. 9.6. Nobi Plain, Japan, in: J.F. Poland (ed.), Guidebook to studies of land subsidence due to ground-water withdrawal, UNESCO, Paris, pp. 195-204.

Zhang, J., Hori, T., Tatano, H., Okada, N., Zhang, C. and Matsumoto, T (2003): GIS and flood inundation model-based flood risk assessment in urbanized floodplain, Proceedings of the International Conference of GIS and Remote Sensing in

Hydrology, Water Resources and Environment (ICGRHWE) at Three Gorges Dam construction site, China from September 16 to 19, 2003, pp. 1-8.

要旨

本研究では都市化の進展や産業構造の変化に伴って、河川汚染リスクが複雑化・複合化している可能性について指摘する。その際、低頻度・甚大被害リスクに特に着目する。公表されている PRTR データベースを活用することにより、この種の複合リスクの特定とその潜在的危険性の評価のための研究アプローチと方法論を議論する。具体的には名古屋都市圏を対象に分析を行う。併せて、今後のデータ・情報の整備の必要性についても検討する。

キーワード： 汚染、氾濫、河川、事故、PRTR、水質、流域管理、リスク分析、土地利用

河川汚染複合リスク評価－研究展望、諸問題と方法論

Jens Hartmann, 岡田憲夫, Jason Levy

1. はじめに

本研究では、日本において都市化の進展や産業構造の変化に伴って、河川汚染リスクが複雑化・複合化している可能性について指摘する。その際、低頻度・甚大被害リスクに特に着目する。公表されている PRTR データベースを活用することにより、この種の複合リスクの特定とその潜在的危険性の評価のための研究アプローチと方法論を議論する。具体的には名古屋都市圏を対象に分析を行う。併せて、今後のデータ・情報の整備の必要性についても検討する。

2. 低頻度・甚大被害リスクとしての河川複合汚染リスク

日本においては、これまでの環境行政の重要性の高まりにつれて、環境リスクの視点からさらに質の高いマネジメントが求められるようになってきている。その結果、河道に定常的に排出される汚染物質のもたらす複合汚染リスクが大きな関心事となってきている。さらに本研究では、発生頻度は低いものの、いったん起こったときには甚大な被害になりかねないような、いわゆる低頻度・甚大被害リスクを問題として取り上げることにする。たとえば内水域に立地する工場において日常的に取り扱われている化学物質が、洪水氾濫などにより漏出し、河川に流出することにより発生しうる複合汚染のリスクも研究の対象となる。この種の事故は、幸いこれまで日本で現実化してことはほとんどないが、都市化の進展と都市機能の複雑化や産業構造の変化に伴って、そのリスク評価はますます不可欠になってきていると考えられる。欧州では現実にそのようなリスクが顕在化する事態も起こってきている。

3. PRTR データベースの利用

指定された化学物質を取り扱う生産施設・工場などに対して、その排出・移転の実態を報告させ、記録することが多くの先進諸国では義務付けられている。さらにそれをデータベースとして整備し、公表する国際的なシステムが PRTR データベースであり、日本もこれが一般の利用に供されている。本研究では河川複合汚染リスクを評価していくための情報基盤としてこのデータベースが活用できることを指摘する。

4. 名古屋都市圏におけるケーススタディ

対象地域として、東海集中豪雨に見舞われた名古屋都市圏を対象に、PRTR データベースや関連行政機関から提供されたデータを活用して分析することを試みた。その際、以下の 5 つの分析を行うこととした。

a. 情報ギャップ分析: 年間の排出量と排出原は分かっているが、河道においてそれがモニターされていない化学物質の特定とその影響分析

b. 流水が低水状態になったときに生起しうる汚染リスクの特定とその影響分析

c. 洪水氾濫により起こりうる汚染リスクの特定とその頻度分析

d. 洪水氾濫により起こりうる汚染リスクについての影響分析

e 河道に排出された複数の化学物質の複合的影響に関する分析

5. 結び

本研究では以上の分析を多角的に行うことにより、今後この種の問題にアプローチしていくための研究アプローチの枠組みと、方法論の提案、ならびに今後の課題について基礎的な知見を提示した