Categorisation of data needed for water quality assessment
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Abstract

Environmental monitoring programs are designed to provide environmental data. Recently monitoring is conducted for two reasons: background monitoring and impact monitoring. Data obtained in monitoring programs describe abiotic and biotic parameters of the environment. They are used to assess the state of the environment and for risk analyses. Data on abiotic characteristics are abundant, could be compared between different sampling sites and have low level of uncertainty. Contrary, data on biotic parameters are scarce with high level of uncertainty. For risk assessment the most crucial are ecotoxicity data. Majority of them are obtained in toxicity tests conducted with animal or plant organisms. Although these data have not high level of reliability in describing ecotoxicity of pollutants, at present they are the only data on toxicity obtained in routine, legally adopted procedures. In the future, every county should have a set of ecotoxicity tests adapted for specific characteristics of their ecosystems. Some of them should be carried out regularly others occasionally with regard to the degree of pollution. Only when both abiotic and abiotic measurements of environmental parameters are performed than risk assessment would provide relevant information for decision making.

1 Introduction

By tradition most evaluations of the quality of the aquatic environment have been based on measurements of a set of concentrations and physical partitions of inorganic and organic substances in the water. Other parameters such as the amount of water, physical and biotic elements of the water body have only recently been considered to be of equal importance as the
characteristics of water for determining the quality of the aquatic environment, Stanners & Bordeau [1].

Water bodies can be fully characterised by three major components: hydrological, physico-chemical and biotic component. A complete assessment of the state of aquatic environment is based on appropriate monitoring of these components.

In environment affected by human activity like discharge of pollutants into aquatic environment, the ordinary monitoring programs are not sufficient to describe the state of the aquatic environment. Pollution of the aquatic environment means the introduction of foreign compounds and energy by men, which result in deleterious effects such as harm to biota, hazard to human life, hindrance to aquatic activities (fishing) etc.. In polluted environment ordinary monitoring programs provide data on changes through time and thus information on the intensity of changes caused by man. However, these data could not be used to describe the effects of pollutants. Data on the effects of pollutants can provide ecotoxicity measurements.

The aim of our paper is to make an review of the existing sets of environmental data and monitoring programs which provide these data. An example is given on the state of surface water quality in Slovenia in comparison to some other countries and standards. Data needed for risk assessment are discussed. It is proposed that all environmental data are categorised before they are used in the risk or quality assessment models.

2 Environmental data

2.1 Environmental data for water quality assessment

The main reason for the assessment of the quality of aquatic environment has been, the need to verify whether the observed water quality is suitable for intended uses. The process of water quality assessment is an evaluation of the physical, chemical and biotic nature of water in relation to natural quality, human effects and intended uses which may affect human health and the health of the aquatic system itself.

Description of the quality of the aquatic environment can be undertaken in a variety of ways. It can be achieved either through quantitative measurements (physico-chemical determinations, biochemical-biological determinations) or through semi-quantitative and qualitative descriptions (biotic indices, species inventories etc.). These determinations are carried out in the field and in the laboratory and produce various types of data which land themselves to different interpretative techniques, Chapman [2].

Water quality monitoring is the collection of data at set locations and at regular intervals in order to provide the information which may be used to define current conditions and establish trends. The reason for monitoring is to determine trends in the quality of the aquatic environment and how it is
changed by the release of chemicals. Recently monitoring is conducted for two reasons: background monitoring and impact monitoring.

2.1.1 Water quality in Slovenia / an example

Water quality is monitored in water monitoring programs in which physico-chemical, hydrological and microbiological parameters are measured. These data provide an overview on the concentrations of chemicals in water bodies. Table 1 shows the concentration range of some metals in our rivers.

<table>
<thead>
<tr>
<th>µg/l</th>
<th>Cu</th>
<th>Cd</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slovenian rivers</td>
<td>10 - 70</td>
<td>8</td>
<td>50 - 85</td>
<td>55 - 160</td>
<td>300 - 430</td>
</tr>
<tr>
<td>Unica / example</td>
<td>&lt; 70</td>
<td>&lt; 2</td>
<td>&lt; 25</td>
<td>&lt; 15</td>
<td>&lt; 135</td>
</tr>
<tr>
<td>classification (see Tab. 3)</td>
<td>II</td>
<td>II</td>
<td>II</td>
<td>I - II</td>
<td>I</td>
</tr>
</tbody>
</table>

Table 1. Annual mean metal concentrations in Slovenian rivers and metal concentrations along river Unec, HMZ [3].

The concentrations of metals as well as other measured compounds in surface water in Slovenia are in the range of concentrations described for other European rivers (Table 2). One of the most admissible parameters in water quality assessment is the amount of metals present in the water (Table 3).

<table>
<thead>
<tr>
<th>µg/l</th>
<th>Nº river stations</th>
<th>Drinking water standards EC</th>
<th>Rivers in Europe µg/l</th>
<th>Clean river</th>
<th>River Volga / example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>192</td>
<td>100 - 3000</td>
<td>1,6 - 16,0</td>
<td>2 - 5</td>
<td>7</td>
</tr>
<tr>
<td>Cd</td>
<td>145</td>
<td>5</td>
<td>0,0 - 1,8</td>
<td>1</td>
<td>0,5</td>
</tr>
<tr>
<td>Cr</td>
<td>56</td>
<td>50</td>
<td>1,3 - 17,0</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Ni</td>
<td>48</td>
<td>50</td>
<td>0,8 - 17,0</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Pb</td>
<td>72</td>
<td>50</td>
<td>0,8 - 11,0</td>
<td>/</td>
<td>1,3</td>
</tr>
<tr>
<td>Zn</td>
<td>176</td>
<td>100 - 5000</td>
<td>5,0 - 91,0</td>
<td>5</td>
<td>22,5</td>
</tr>
</tbody>
</table>

Table 2. Annual mean metal concentrations in European rivers and concentrations in river Volga, Stanners & Bordeau [1].
<table>
<thead>
<tr>
<th>µg/l</th>
<th>I. class</th>
<th>II. class</th>
<th>III. class</th>
<th>IV. class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>&lt; 30</td>
<td>&lt; 100</td>
<td>&lt; 140</td>
<td>&gt; 140</td>
</tr>
<tr>
<td>Cr</td>
<td>&lt; 75</td>
<td>&lt; 150</td>
<td>&lt; 800</td>
<td>&gt; 800</td>
</tr>
<tr>
<td>Ni</td>
<td>&lt; 50</td>
<td>&lt; 50</td>
<td>&lt; 140</td>
<td>&gt; 140</td>
</tr>
<tr>
<td>Pb</td>
<td>&lt; 80</td>
<td>&lt; 50</td>
<td>&lt; 140</td>
<td>&lt; 140</td>
</tr>
<tr>
<td>Zn</td>
<td>&lt; 650</td>
<td>&lt; 200</td>
<td>&lt; 1400</td>
<td>&gt; 1400</td>
</tr>
</tbody>
</table>

Table 3. Classification of surface water into four quality categories regarding the metal concentration in the water, HMZ [3].

<table>
<thead>
<tr>
<th>µg/l</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking water standards</td>
<td>5</td>
<td>50</td>
<td>1000</td>
<td>/</td>
<td>50</td>
<td>5000</td>
</tr>
<tr>
<td>Fisheries and aquatic life</td>
<td>0.2 - 2</td>
<td>2 - 20</td>
<td>2 - 4</td>
<td>25 - 150</td>
<td>1 - 7</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4. Drinking water standards and concentrations of some metals in surface water used for fisheries and aquatic life in Canada, Chapman [2]. Note that much more strict standards for fisheries and aquatic life than for drinking water.

Routine monitoring program of water quality in Slovenia similar to other countries is based on monitoring of chemical compounds, physico-chemical and hydrologic parameters and on some biotic analyses. This monitoring provide data on the aquatic environment in order to define its use (Table 4).

In the case of pollution or any other changes in the water environment the routine, background monitoring program has to be supplemented with ecotoxicity measurements. Only than risk analyses of a real situation could be performed.

2.2 Risk assessment

The term risk is a term in ordinary language with vague meaning as well as a technical term in environmental and health policy. In this context the term has quite different life as a technical term that is defined precisely within carefully calibrated scientific models for risk assessment. The ordinary concept of risk assessment involves complexities that cannot be fully comprehended in any single model. It is therefore not possible to identify and support a single risk model as the exclusively correct one. The best we can hope for is to construct a
variety of risk analysis models, to be as precise as possible in developing them, and to learn what we can from a variety of models under diverse applications. It must always be remembered, that we are not looking for the “right” risk model, but rather the model that will illuminate risk as it is addressed in particular context, and for the insight that can be gained by looking at a complex thing through multiple lenses, Norton [4].

2.3 Ecotoxicity data in theory and praxis

Ecotoxicity data are data on the effects of chemicals on organisms. Ecotoxicity data are obtained in ecotoxicity analyses mostly in toxicity tests, e.g. Calow [5], Rand [6].

Usually, toxicity tests are conducted in the laboratories under controlled conditions resembling a certain degree of field situation. They could be designed either on animal or plant organisms. In toxicity tests the responses of test organism to elevated concentrations of chemicals are measured. The organisms respond to chemicals at different levels of biological organisation ranging from biochemical to population or community level.

Toxicity tests at lower levels of biological organisation (biochemical, cellular, histological level) are fast, controlled, specific for tested chemical, easy to perform, repeatable and cheap. Toxicity tests at higher levels of biological organisation (behavioural, population, community level) are more relevant and reliable to describe ecotoxicity, but these tests are difficult to conduct, they are less specific, less controlled, expensive and the results are difficult for interpretation.

In all cases, weather toxicity tests are conducted on one or more species, in laboratory controlled conditions or under field reassembling environment, the results could not be extrapolated to all other members of the community. Chemicals which are toxic to species used in the toxicity tests are not necessarily toxic to the same degree to other species in the ecosystem. For other members of the community tested chemicals can be either more or less toxic.

In the future ecotoxicity testing, the most promising are landscape toxicity indexes and sensitive biomarkers of early disturbances of the polluted environment, Hoffman et. all [7]. However, standard toxicity tests will probable keep their central position in the early screening of the effects of chemicals and to assess the toxicity of chemicals before they are released into the environment. Namely, single-species or multi-species toxicity tests produce data on the toxic effects of chemicals present in the environment and these data are indispensable needed for any risk assessment model.

At present there are many toxicity test protocols available for routine use, e. g. Rand [6], Drobne & Hopkin [8], Drobne [9]. Only a few of them have been legally adopted. There are many reasons for that. Among them the most important is that every environment has specific responses to pollutants and needs specific selection of toxicity tests.
The other difficulty in toxicity studies is to separate changes in ecological systems caused by anthropogenic impacts from normal changes which are called “natural changes” or “background variability” of measured parameters. All this shows how complicated methods which provide ecotoxicity data are. Besides, the nature of uncertainty of ecotoxicity data is higher than for any other environmental data. Analysts often know a great deal about the nature of uncertainty. But this information is usually ignored or forgotten. When knowledge about the nature of uncertainty is included in the ecotoxicity data, decision makers can often place greater reliance on the outcome of analysis. Inclusion of data on uncertainty can be accomplished in key steps of the risk assessment. Each of analytical steps must expose its uncertainties if an honest picture of available knowledge is to be presented.

In praxis, ecotoxicity data are needed when toxicity of chemicals are tested in the polluted environment. But before we test pollutants for toxicity, we need a lot of knowledge on the physiological, biological and ecological characteristics of animals used in the testing protocol, on their role in the ecosystem, on the responses of organisms to reference toxic substances etc.. More background knowledge is available on the testing organism, more reliable ecotoxicity data can be.

In the future we expect more information from biochemical, physiological, biological and ecotoxicity studies and hence toxicity testing methods could provide more reliable data.

3 Categorisation of environmental data

Environmental reports contain data on the chemical compounds, hydrological and physicochemical parameters, data on some microbiological analyses and sometimes, not as a rule a description of selected (indicator) plant and animal species in the ecosystem, Stanners and Bourdeau [1], HMZ [3]. Information gained upon these data is limited in interpreting the quality of the environment and not sufficient for any risk analyses. Even when these data are completed with ecotoxicity data (effects of chemicals on living organisms) or ecological data (structure and function of the ecosystem) they are still of a limited value unless interpreted properly.

The most relevant way how to process environmental data is by the use of models. However, improper models give wrong and misleading interpretations of the data. A problem with environmental data processing is that we have to deal with basically different groups of data to produce a single information (for example, the degree of risk).

Data on physico-chemical and hydrological parameters are abundant, available for different sampling sites and allow a high degree of comparison between site. These data have relatively small degree of uncertainty, which can be determined in explicate terms.
Data on living organisms and their communities are scarce, have low degree of comparability between different sampling sites and have high degree of uncertainty, which is difficult for determination and can be rarely expressed in explicate terms.

Because of these differences, data obtained in abiotic and biotic measurements, may not be mixed and processed on the same way/in the same model. We suggest, that environmental data should be first categorised according to their origin (abiotic or biotic measurements), their level of uncertainty and level of comparability between different sampling sites. The information obtained from different sets of data could than be processed further either for risk assessment or quality assessment. Categorisation of data into different groups gives the data another quality. It becomes transparent which group of data influences more the final information and which data are needed to make that information more relevant in the process of decision making.

In all cases where the models on the toxicity of chemicals to water organisms are developed, we must be aware that this relationship is complex and interactive and it is difficult to incorporate the spatial and temporal heterogeneity of the water medium as well as the behaviour and physiological characteristics of water organisms into a model. No matter what data do we have all models using data on organisms are of limited value. If data on higher biological organisation is used in the model, the output information is even more vague, than in the case of data from lower levels of biological organisation. In the future, the importance will be posed on the understanding of functioning of the ecosystem under normal and under stressed conditions. Only than the environmental data could be modelled to produce reliable information on the quality of the environment, on its present and future status.

4 Discussion

Most pollution problems have evolved unrecognised over time until they have become apparent and measurable. Recognition of a problem, therefore, took considerable time and control measures took, in most cases, even longer.

Average rang of Slovenian surface water quality is in the upper half compared to the average European surface water quality. In Slovenia EU standards are used for water quality control, although some of them should be adapted for specific environmental characteristics in some Slovenian regions (karst region, downfall regime, Pannonian level, etc.). In these standards recommended or illicit levels of chemicals are stated. There are no regulations for biotic component of the environment. There are however some recommended standardised toxicity test protocols available for routine use. The selection of ecotoxicity methods fall under jurisdiction of state or regional authorities.

In Slovenia, there are not extremely polluted areas as in highly industrialised regions, hence not enough attention was put toward development
and application of ecological and ecotoxicological methods. We have adopted
some ecotoxicological methods for surface water assessment, Grbović [10],
Brilly, Grbovoč & Gorišek [11], however there is an evident need to develop
our own methods for our specific environments.

Large variations are found between rivers or lakes in different continents
or in different hydroclimatic zones. The reason for this is complexity of factors
determining water quality. Similarly, the response to anthropogenic impacts is
also highly variable. As a consequence, there is no universally applicable
standard which can define the baseline chemical or biotic quality of waters.

Every country has to formulate its own standards for the quality of the
environment in accordance to international agreements. Adopted national
standards should be based on the characteristics of the country, measurements
in the field, professional judgements, environmental policy and environmental
ethics. All these components have to be balanced. In Slovenia, similar to other
new countries some of these components have anomalous proportion or are
neglected. As a matter of fact, the only reason for poor environmental policy is
not economic situation, as one might think, but to much higher degree the
importance that was/is posed to environmental issues in the society.

5 References


