Impact assessment of construction material plants on water bodies

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Abstract. This paper is about the impact of pollution caused by construction material plants on water bodies. For this purpose, the authors have analyzed manufacturing procedures, water consumption, and a discharge scheme and also calculated quantitative composition of wastewater and allowable discharge standards for a selected manufacturing plant. Based on the analysis of existing wastewater treatment methods, the authors have discovered new wastewater treatment schemes with the help of the best available technologies. Calculating the efficiency of these schemes, the authors have found out that the implementation of these schemes will provide observance of allowable discharge standards in wastewaters.

1 Introduction
Nowadays construction material plants are growing immensely. The increase in production volumes in these plants results in the growth of both water consumption and wastewater discharge, which in turn results in the growth of effluent charges. Besides these, the requirements of water quality protection are also increased. That is why manufacturing plants have to reduce the negative impact of wastewater discharge on water bodies by introducing modern sewage treatment methods.

The latest technological developments in wastewater treatment are presented in detail in the articles written by various researchers from France, China, Germany, Sweden and the USA [1–9]. They have paid careful attention to the newest methodology in the construction of sedimentation tank, and with their new technological solutions they have executed a multipronged attack on the problem. However, such modification of copper alloys is promising from several points of view.

In this research we have done impact assessment of wastewater discharge from construction material plants on a water body and arrived at solutions for the reduction in wastewater discharge, taking up a selected manufacturing plant as an example.

2 Methods and objectives of research
Pervaya Rechka is one of the smallest rivers of Vladivostok in Primorsky Krai. The length of the stream is 8.8 km, and watershed area is 20 km². The river arises from the west flanks of Central Mountain Range, flows west, and disembogues into Amur Bay between Lagerny and Kaluzina promontories. Pervaya Rechka is an important stream for commercial fishing. Longterm observations of Pervaya Rechka show that its contaminant level increases every year. The results of physicochemical analysis show that significant extent of pollution was caused by iron, phenols, oil products, and zinc. It is mainly because of the fact that the major part of the watershed is occupied by many industrial facilities and residential constructions, which constitute the notable segment of the
city’s infrastructure.

One of the largest industrial facilities situated in the watershed is a construction material plant – ZAO «VKPP» (Vladivostok combine of complementary industrial plants) – which discharges wastewater into Pervaya Rechka, contributing to its significant increase in the water contaminant level.

The main production process of this plant is manufacture of cement mortar, ready-mixed concrete, reinforced concrete structures, bitumen concrete mix, and other concrete products. It also manufactures core and auxiliary products. There are also asphalt mixing plants, concrete mixing and lime-slaking plant floor, and molding and assembly plant floor for core production.

Based on its requirements, the manufacturing plant gets water from two sources. Water from its borehole is used for the production of cement mortar and ready-mixed concrete, and cooling compressor system. For other manufacturing processes, chores, and practical needs they use the city’s main water supply system.

There are two types of wastewater in the city: domestic wastewater, which is discharged into public sewer system, and combination of storm water and industrial wastewater, which is discharged into Pervaya Rechka. The manufacturing plant has a sewage treatment plant which consists of a sand/gravel filter and a horizontal flow sedimentation tank, where wastewater is treated from suspended substances, oil products, and organic substances.

Based on the concentration of polluting substances observed from the records of water sampling (2009–2014) and the volume of water consumption, we have estimated the actual mass of pollutant discharge by equation (1):

\[ m_{\text{act.}} = C_{\text{act.}} \times q_{\text{act.}} \]  

where \( C_{\text{act.}} \) is the actual concentration of a polluting substance (mg/dm\(^3\)); \( q_{\text{act.}} \) is the actual volume of wastewater (m\(^3\)/year).

Allowable discharge standards of polluting substances were calculated by equation (2), according to an authorized method:

\[ m_{\text{ads.}} = C_{\text{ads.}} \times q \]  

where \( C_{\text{ads.}} \) is the allowable concentration of the polluting substance (mg/dm\(^3\)); \( q \) is the volume of wastewater (m\(^3\)/year).

Allowable concentrations of substances in wastewater \( C_{\text{ads.}} \) were determined by equation (3):

\[ C_{\text{ads.}} = n \times (C_{\text{act.}} - C_{\text{back.}}) + C_{\text{back.}} \]  

where \( C_{\text{act.}} \) is admissible concentration limit of the polluting substance in the water (mg/dm\(^3\)); \( C_{\text{back.}} \) is the background concentration of the polluting substance in the water upstream from the point of discharge (mg/dm\(^3\)); \( n \) is the rate of wastewater dilution in the stream.

3 Results and discussion

Based on the analysis of the manufacturing activities and the actual concentrations of polluting substances in wastewater, we have observed the following sources of pollutants. Wastewater from the asphalt mixing plant is polluted with oil products, phenols, and suspended substances. Wastewater from concrete mixing and limeslaking plant floor contains suspended substances, iron, surface-active agents, and copper. Emulsified oil products, zinc, surface-active agents (+phosphates), and phenols are found in the wastewater from molding and assembly plant floor. Storm water is polluted with suspended substances, oil products, and organic substances (biological oxygen demand).

The results of the calculation of actual mass of pollutant discharge (2009–2014) and comparison of them and the calculated standards are presented in figures 1–4.

The maximum discharge of suspended substances was recorded in 2013 – exceeding 3.4 times, and organic substances (biological oxygen demand) in 2011 –11.7 times (figure 1).

The maximum exceedance of phosphates discharge was observed in 2012 – by 3.4 times (figure 2). Actual discharge of oil products is constantly above allowable level. Moreover, in 2012, it exceeded the standard 9.1 times. Discharge of surface-active agents also exceeded in 2009 –6.2 times.

More significant exceedance is observed in copper –70 times in 2012, and in zinc –7.3 times in
2013 (figure 3). The maximum of discharged mass of total iron was recorded in 2009 – exceeding 30 times and dissolved iron – 58 times (figure 4).

Figure 1. Allowable standards and trends of actual mass discharge of polluting substances (suspended substances, biological oxygen demand).

Figure 2. Allowable standards and trends of actual mass discharge of polluting substances (phosphates, oil products, surface-active agents).

Figure 3. Allowable standards and trends of actual mass discharge of polluting substances (copper, zinc, phenols).

Figure 4. Allowable standards and trends of actual mass discharge of polluting substances (total iron, dissolved iron, ammonium ion).

From the analysis of wastewater treatment system and the results of quantitative and qualitative composition of wastewater, we have identified the following problems:

– industrial wastewaters and storm water are not separated (they are combined and discharged into Pervaya Rechka);
– the manufacturing plant in question has not got modern sewage treatment system, and its existing system does not provide effective treatment, meeting allowable discharge standards;
– wastewater discharge from the plant exceeds the admissible concentration limit by many times in the water bodies.

We have also researched on the plant’s manufacturing procedures, water consumption, and discharge system and come up with a proposal for modernization:

– set apart industrial wastewaters and storm water;
– develop a sewage treatment system based on modern methods.

The analysis of quantitative and qualitative composition of wastewater has shown that the prominent polluting substances in industrial wastewater are suspended substances, oil products, surface-active agents, copper, zinc, iron, and phosphates. In storm water, there are suspended substances, oil products, and biological oxygen demand. During the development of the proposal we
chose appropriate methods of treatment based on profound analysis of literature sources, taking into account the best available techniques described in [10]. Furthermore, they were combined with manufacturing schemes focused on observance standards of polluting substances in wastewater.

The scheme of industrial wastewater treatment can be summarized as shown in figure 5. Wastewaters go through bar screen and oil separator to sedimentation tank regulator. Averaged water is conveyed into coagulation and flocculation unit where floc formation occurs, caused by aluminum sulfate as coagulant and polyacrylamide as flocculant. Settled sludge goes to impounding basin and then into pressure filter for deliquification. Water in effluent filter, along with water from the coagulation and flocculation unit, gets into the filter with polystyrene foam core.

![Figure 5. Scheme of industrial wastewater treatment.](image-url)

Based on the specified treatment efficiency of each method and unit, and taking into account the initial concentrations of each substance, we have calculated concentrations after the treatment. The results are shown in table 1. Industrial wastewater treatment efficiency is approximately 86–99.5% depending on the polluting substance. This treatment scheme provides observance of allowable discharge standards in wastewaters.

| Substance          | Concentration before treatment, mg/l | Concentration after treatment, mg/l | $C_{adv}$, mg/l | Treatment efficiency, % |
|--------------------|--------------------------------------|-------------------------------------|-----------------|-------------------------|
| Suspended substances | 81.7                                 | 0.41                                | 18.85           | 99.5                    |
| Oil products       | 0.6                                  | 0.0036                              | 0.05            | 99.4                    |
| Copper             | 0.078                                | 0.000936                            | 0.001           | 98.8                    |
| Iron               | 9.7                                  | 0.291                               | 0.3             | 97                      |
| Zinc               | 0.081                                | 0.00486                             | 0.01            | 94                      |
| Phosphates         | 0.31                                 | 0.031                               | 0.082           | 90                      |
| Surface-active agents | 0.221                              | 0.03094                             | 0.034           | 86                      |

The second scheme of storm water treatment can be summarized as presented in figure 6. Wastewaters go through the bar screen into the sand/gravel filter and then into the thin-layered
horizontal flow sedimentation tank oil separator. One of the advantages of this scheme is that it includes components of the available wastewater treatment system.

![Diagram of storm water treatment scheme](image)

**Figure 6.** Scheme of storm water treatment.

Efficiency of this treatment scheme and calculations of concentrations after treatment are shown in table 2. Storm water treatment efficiency is approximately 86–99.5%. This treatment scheme provides observance of allowable discharge standards in wastewaters. Also this scheme is effective for treatment of storm water from oil products, suspended materials, and organic substances (biological oxygen demand).

| Substance                  | Concentration before treatment, mg/l | Concentration after treatment, mg/l | $C_{adv}$, mg/l | Treatment efficiency, % |
|----------------------------|--------------------------------------|-------------------------------------|----------------|------------------------|
| Suspended substances       | 70.6                                 | 7.766                               | 18.85          | 89                     |
| Oil products               | 0.39                                 | 0.03                                | 0.05           | 92.2                   |
| Biological oxygen demand   | 28.595                               | 2.40198                             | 3.0            | 91.6                   |

**Table 2.** Efficiency of storm water treatment scheme.

4 Conclusion

In this study we have analyzed the activities and manufacturing procedures of a construction material plant and assessed its water consumption and wastewater discharge scheme. It was also shown that its wastewater discharge exceeds the admissible concentration limit for polluting substance in water and that its existing sewage treatment system is not adequate to meet the expected standards.

We have calculated the allowable discharge standards and defined quantitative and qualitative composition of wastewater discharged from the manufacturing plant. From the comparative analysis, we could prove significant exceedance of standards by the following substances: oil products, copper, zinc, suspended substances, iron, biological oxygen demand, phosphates, and surface-active agents.

Based on the analysis of the existing wastewater treatment methods in the plant, we have also offered appropriate wastewater treatment schemes for this manufacturing plant. During the research, we took into account special aspects of sewage composition and requirements of admissible concentration limits for the stream – factors that are crucial for commercial fishing.

Implementing the proposed schemes for wastewater treatment will essentially reduce negative impact of the said manufacturing plant on the water body.

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