

# Operational Intervention Levels (OILs)– A Tool to Overcome Differences in Intervention Levels?

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**Abstract:** The intervention levels for evacuation, sheltering and iodine blockade still differ in many countries, although international organisation like IAEA, NEA or ICRP aspire to harmonise them on an international level. Even if the dose values of the limits are in agreement, they are not necessarily comparable because the type of dose (projected dose, averted dose), the respected exposure pathways (external dose, inhalation, ingestion) or the integration time might differ significantly. The question is raised, how can harmonisation be achieved? International organisations recommend “operational intervention levels” (OILs) for promptly assessing the results of environmental monitoring and to decide on protective actions. OILs are measurable values derived from dose limits. Best examples are the derived intervention levels for food and feed in the codex alimentarius or by the EC, which limit the ingestion dose to about 5 mSv/a. This paper discusses the properties and potential use of OILs, identifies and derives useful OILs and addresses their benefit in practise both for early and later countermeasures. Furthermore it is discussed whether OILs might be a useful tool to overcome national differences in intervention levels because an OIL value covers a relative wide range of the projected dose due to the uncertainty of the parameters needed for derivation.

**KEYWORDS:** *emergency preparedness, dose limit, operational intervention level, OIL,*

## 1. Introduction

In a recent publication [1] the International Atomic Energy Agency defines the operational intervention level (OIL) as “A calculated level, measured by instruments in the field or determined by laboratory analysis, that corresponds to an intervention level or action level. OILs are typically expressed in terms of dose rates or of activity of radioactive material released, time integrated air concentration, ground or surface concentration or activity concentrations of radionuclides in environmental food or water samples. An OIL is a type of action level that is used immediately and directly (without further assessment) to determine the appropriate protective actions on the basis of an environmental measurement”.

In the same publication the IAEA recommends. “In addition, arrangements shall be made for promptly assessing the results of environmental monitoring and monitoring for contamination on people in order to decide on or to adapt urgent protective actions to protect workers and the public, including the application of operational intervention levels (OILs) with arrangements to revise the OILs as appropriate to take into account the conditions prevailing during the emergency.” Corresponding recommendations are given in a later safety series publication of IAEA [2] as well as in the new draft of the basic safety standards [3].

As OILs are measurable values which are derived from intervention dose levels, they are of practical importance in case of a nuclear emergency. If measured values meet or exceed the operational intervention level, the corresponding countermeasures have to be taken into account.

Despite of their advantages and although OILs are internationally recommended, corresponding considerations and guidance are rare. Furthermore the wording might be confusing because similar terms are mentioned in international recommendations: action level, generic action level, operational level or derived emergency reference levels. All are measurable values which correspond to a certain dose to man. In this paper “operational intervention levels” are understood as a term which is derived from intervention doses established for the introduction of countermeasures. Internationally “derived emergency reference levels” (DERL) for food and feed are recommended by IAEA/FAO/WHO [4] and the EU [5]. Further mandatory regulations are missing.

In the following, the properties of OILs, their derivation, their use and their benefit are discussed for the early and later countermeasures. As a first step, it is useful to analyse the DERL for food.

## 2. DERL for food

The recommendation in the Codex Alimentarius [4] and the EC levels [5] define DERL as specific activity levels for different kind of food as well as for different groups of radionuclides. If the levels are exceeded, food has to be banned and can not be sold on the market. The values have been derived according to equation (1).

$$OIL = \frac{IL}{t \times f_1 \times f_2} \quad (1)$$

*OIL*: Operational intervention level for food (Bq/kg)

*IL*: Intervention dose for ingestion (5 mSv/a)

*t*: integration time (1a for long lived radionuclides, 40 days for I-131)

*f*<sub>1</sub>: dose conversion factor for ingestion (Sv/Bq)

*f*<sub>2</sub>: Relative contamination factor, quotient between the expected mean specific radionuclide activity in food during one year and the corresponding values for OILs (OILs are maximum values for food. They correspond with a dose of 5 mSv/a. It can be expected, that during one year the average specific activity of radionuclides in food will be lower than the maximum values. Correspondingly the dose to man will be lower according to the ratio between the expected mean annual specific activity in food and the OILs. The relative contamination factor corrects for this effect in the derivation of OILs).

According to the derivation, the DERLs for food correspond to an intervention dose of 5 mSv/a. Comparison of measured values with the DERL enable prompt decisions whether the product can be put on the market or not. The DERL ensure that the dose due to ingestion does not exceed the intervention dose of 5 mSv/a. Taking IAEA's definition of OILs into account, the DERLs for food are nothing else but OILs, a fact which apparently not always has been recognised.

Although the intervention dose is set to 5 mSv/a in both derivations, the resulting OILs differ slightly. Concerning the derivation, only the assumption for the "relative contamination factor" differed in the two approaches. For the EU values a relative contamination factor of 0.4 can be deduced, for the FAO values of 0.5. Correspondingly the EU values are 10 % higher than those of FAO/WHO. As it is always difficult to explain even small differences to the public, a harmonisation of both approaches is highly desirable to gain confidence.

## 3. Consideration OILs for countermeasure of the early period

Countermeasures in the early period are evacuation, sheltering and thyroid blocking. Countries have settled corresponding dose intervention levels. The present values for Germany are indicated in table 1.

Countermeasure	Reference Levels		
	Projected dose to Thyroid	Projected effective dose	Exposure Pathways and Time of Integration
Sheltering		10 mSv	Sum of external dose rate and inhalation dose integrated over 7 days
Thyroid blocking	50 mSv for children until 18 years and pregnant woman,  250 mSv for adults		Inhalation of radioiodine, inhaled within 7 days
Evacuation		100 mSv	External dose integrated over 7 days

**Table 1:** Intervention dose levels for sheltering, thyroid blockade and evacuation in Germany

### 3.1 Derivation of OILs for thyroid blocking and their use and benefit in practice

Thyroid blocking is relevant in the early phase during the passage of a cloud. In this period food should be banned precautionary. Then inhalation is the only exposure pathway to be considered for the derivation of OILs. This means that OILs for thyroid blocking have to be expressed as radioiodine concentration in air. When measurements indicate that the derived OILs are met or exceeded, the intake of iodine tablets have to be recommended to keep the dose to the thyroid below the intervention levels for thyroid blocking.

The equation for the derivation of OILs for inhalation is simple if a constant radionuclide activity in air is assumed

$$OIL = \frac{IL}{t \times f_1 \times a_1} \quad (2)$$

*OIL* operational intervention level for inhalation (Bq/m<sup>3</sup>)

*IL* intervention dose for the thyroid according to table 1(Sv)

*t* integration time (168 h )

*f<sub>1</sub>* thyroid dose conversion factor for inhalation of I-131 (adult: 1.7 x 10<sup>-7</sup> Sv/Bq, infant: 1.4 x 10<sup>-6</sup> Sv/Bq)

*a<sub>1</sub>* inhalation rate of infants (0.1 m<sup>3</sup>/h) and adults, respectively (1 m<sup>3</sup>/h)

Thyroid blocking is a measure which has to be taken into account in the vicinity of a nuclear power plant. The German regulation assumes an integration time of 7 days, although it is not very likely that the wind direction stays stable over this long time span. Another assumption is related to the run of the radionuclide concentration in air with time. In this approach it is simplifyingly assumed that the radioiodine concentration in air stays constant over a period of 7 days. Furthermore, only the dose conversion factor for I-131 is taken into account, because this radionuclide by far dominates the thyroid dose.

According to these assumption, the operational intervention levels are calculated to be roughly 2000 Bq/m<sup>3</sup> I-131 for children and 10 000 Bq/m<sup>3</sup> I-131 for adults.

For the use of the OILs for thyroid blocking in practice it has to be taken into consideration that thyroid blocking is a precautionary countermeasure. To be efficient iodine tablets should be taken about half an hour before the radioactive cloud arrives. This means the initial recommendation have to be given based on very uncertain results of decision supporting models. Measurements of radioiodine in air and their comparison with the OILs are the first tool to verify the (further) need of stable iodine intake during the passage of the radioactive cloud.

Automatic measurements of the radionuclide concentration in air as well as of the external dose rate are recommended in emergency monitoring programs for the early time period. In practice the air measurement network is too wide to identify the areas of concern precisely. It is therefore recommended to use results from the significantly denser external dose rate net in addition. For early decisions it will be sufficient to assume that the contribution of radioiodine to the external dose is constant during a single air sampling and measurement period.

### **3.2 Derivation of OILs for sheltering and evacuation and their use and benefit in practise.**

Concerning sheltering and evacuation it has to be recognised that more than one exposure pathway contribute to the reference dose. Direct radiation and inhalation are the dominant exposure pathways because in Germany as in many other countries food will be banned precautionary in the early period. This implies that OILs can be defined as air concentration and external dose rate.

In practice, the measurements of the external dose rate will usually be chosen to evaluate the radiological situation because it can be monitored more easily, more frequently and in higher density than the radionuclide concentration air. Thus early decision on sheltering and evacuation will be reviewed first by comparing dose rate measurements with the corresponding OILs. Later, results on measurements of air concentration can be considered as an additional criterion to evaluate the radiological situation.

As external radiation is not the only exposure pathways to consider sheltering and evacuation, it is suggested to assume that inhalation and external dose rate contribute in the same amount to the total dose. The OILs for external dose rate can be derived in a straight forward approach. The total dose is assumed to be 50% of the reference dose level divided by  $t = 168$  h. With these assumptions sheltering would be relevant for external dose rates of or above  $15 \mu\text{Sv/h}$ , (evacuation:  $150 \mu\text{Sv/h}$ ).

Eq. 2 can be adopted for the derivation of OILs for radionuclide concentration in air. The assumptions should be in agreement with the assumptions for the derivation of OILs for thyroid blocking, i.e. constant radionuclide concentration in air and integration time of 7 days. As usually a radionuclide spectrum is expected, OILs for different groups of radionuclides need to be considered. Due to the significant differences in dose conversion factors, at least a distinction between  $\alpha$ -emitters and others radionuclides is essential.

As example, a constant air concentration of about  $0.4 \text{ Bq/m}^3$  Pu239/240 or  $400 \text{ Bq/m}^3$  Cs-137 will result in an inhalation dose of 2.5 mSv to an adult, using dose conversion factors of  $4.3 \times 10^{-5} \text{ Sv/Bq}$  for Pu239/240 and  $3.9 \times 10^{-8} \text{ Sv/Bq}$  for Cs 137 with an inhalation rate of  $1 \text{ m}^3/\text{h}$ .

## **4. Long term Countermeasures**

### **4.1. General situation**

The dynamics of radionuclides in the environment is slow after the passage of a cloud and the end of deposition. The distribution of radionuclides in the environment stays fairly stable. Radioactive decay is usually the main reason for the disappearance of radionuclides in the environment. For an adequate emergency response it is essential that the contamination of the environment will rapidly be evaluated by measurements. A corresponding monitoring programme has to be evaluated. Therefore it can be assumed that detailed contamination maps are available.

In this situation decisions have to be taken on agricultural countermeasures, on additional evacuation (relocation, resettlement) and/or on returning into evacuated areas.

## 4.2 Agricultural Measures

The question of banning agricultural products is covered by the OILs for food and feed. Concerning the long term contamination of food, root uptake instead of direct deposition will be the major contamination pathway. For a prognosis of the contamination of food, the amount and the spectrum of radionuclides in soil have to be known. OILs defined as radionuclide concentration in soil might roughly indicate where agricultural countermeasures to lower the radionuclide uptake might be appropriate. They have to be derived from the intervention levels in food:

$$OIL_{soil} = \frac{OIL_{food}}{TF_r} \quad (3)$$

$OIL_{soil}$  operational intervention level for the specific radionuclide activity in soil (Bq/kg)

$OIL_{food}$  operational intervention level for the specific radionuclide activity in food (plant products) respectively feed (Bq/kg)

$TF_r$  transfer factor soil/plant for radionuclide r

As examples the OILs for Cs-137 would be 25 000 Bq/kg and for Pu239/240 about 2500 Bq/kg soil (transfer factor soil/plant for Cs:  $5 \times 10^{-2}$  and for Pu  $4 \times 10^{-4}$ ). In practice the OILs can only be very generic values because the TF depends on many parameters including fruit type and soil properties. Resuspension might play a role. Therefore, OILs for soil contamination might merely be a general indicator of the need of agricultural countermeasures. At least site specific investigations are recommended for final decisions. Furthermore the ALARA principle is still valid, which implies that objectives of restoration might be more ambitious.

## 4.3 Evacuation and Returning

For decisions on additional evacuation and on returning, the projective dose to man will be calculated on the basis of the external dose rate measurements and the corresponding radionuclide spectrum. The question is raised what could be the benefit of OILs in this time period, when corresponding dose and contamination maps are already available? Is there a need for OILs at all in the late phase?

Rapid measurements could support more detailed information in the area of concern especially in urban areas where heterogeneous deposition patterns are likely. As the dose to man depends on the deposited radionuclide spectrum the OILs should be adopted to the existing situation and in agreement with advanced dose calculations.

As the radionuclide concentration in air will be low and the ingestion pathway is covered by OILs for food and soil, the external dose rate is the relevant exposure pathway for decisions on late evacuation and returning. Consequently the OILs for external dose rate have to be based on the measured ODL and on the radionuclide spectrum deposited on ground causing the external radiation. If only long lived radionuclides have to be taken into account, OILs can be derived by division of the intervention dose by the number of hours per year. For a dose of 100 mSv/a as accepted in many countries, the corresponding OIL will be about 10  $\mu$ Sv/h. If short lived radionuclides are present, OILs might be adjusted with time according to following equation:

$$H_{total} = \int_{t=0}^{t_a} H_t \cdot e^{-\lambda_{eff} \cdot t} \quad (4)$$

$H_{total}$  intervention dose for evacuation or returning (Sv/a)

$H_t$  initial dose rate = OIL (Sv/h)

$\lambda_{eff}$  effective half life of the radionuclide spectrum (h)

$t_a$  integration time ( 1a)

## 5. Conclusion

OILs are measurable values which are derived from intervention doses. If the operational intervention level is met or exceeded, the corresponding countermeasure has to be taken into account. Levels which are derived from doses other than the intervention ones should be named operational level only. Operational levels and operational intervention levels might be summarised as action levels.

During the passage of a cloud, the comparison of measurements of the external dose rate and of the radionuclide concentration in air with OILs will be a first, fast and reliable tool to evaluate the radiological situation. In the later phase OILs are of special value for detailed identification of areas of concern. Generally they are a very useful tool for promptly assessing the results of environmental monitoring to decide on protective actions. This attribute makes them also attractive for a dialogue with the public.

Countermeasure	Intervention dose	Exposure pathway	Operational intervention level
Early countermeasures			
Sheltering	10 mSv/7days	Direct radiation Inhalation	15 µSv/h 0,4 Bq/m <sup>3</sup> Pu239/240 400 Bq/m <sup>3</sup> Cs-137
Evacuation	100 mSv/7days	Direct radiation Inhalation (adults)	150 µSv/h 4 Bq/m <sup>3</sup> Pu239/240 4 000 Bq/m <sup>3</sup> Cs-137
Thyroid blocking	50 mSv/7days to the thyroid for children until 18 years  250 mSv/7days to the thyroid for adults	Inhalation	2000 Bq/m <sup>3</sup> I-131  10 000 Bq/m <sup>3</sup> I-131
Long term countermeasures			
Food	5 mSv/a	Ingestion - food	See [4] and [5]
Agricultural measures	5 mSv/a	Ingestion - soil	25 000 Bq/kg Cs-137 2 500 Bq/kg Pu239/240
Evacuation and Returning	100 mSv/a	Direct radiation	10 µSv/h

Table 2: Summary of the OILs derived in this study for different countermeasures

Because of their easy applicability, the use of OILs in case of nuclear emergencies is strongly recommended. The set of values derived in this study is summarised in Table 2. It should be noted that they are based of a number of simplifying assumptions and, therefore, should be used with caution only. More detailed derivations are highly appreciated.

Taking into account the simplifications and uncertain assumptions included in their derivations, OILs could also become a tool to agree internationally on a set of OIL values and thus to overcome national differences in intervention levels.

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